Fiscal Year

2005

Human Factors Technical Program Review

Federal Aviation Administration

Human Factors Research & Engineering Division

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A New Equation

Right Strategies, Strong Focus, Execution, World-Class Results

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To the Aviation Community

The Human Factors Research and Engineering Division (ATO-P R&D) is committed to sustaining leadership in applying our discipline to civil aviation through the conduct and use of world-class, cutting edge research, engineering and development. To do this, our human factors research program needs to be flexible, balanced and dynamic. We interpret this to mean that, like any successful business, we have to provide value to our customers. It also means we must respond to critical near-term needs outlined in *Flight Plan 2006-2010*, while simultaneously providing a solid foundation for the *Next Generation Air Transportation System*. I am happy to report that we met these challenges in 2005.

Business value to our customers equates to R&D for the Real World. A good example is our development of a revised FAA Tower Siting Policy (released in July 2005). This important achievement establishes a requirement and criteria, as well as a tool that incorporate human visual perspective and performance capabilities to support tower height and location decisions at the least cost. Where the tendency has been for towers to be built at increased heights (exceeding heights required for human visual discrimination), the expected decrease in tower heights (by 10-40 feet/tower) offers potential cost savings of $5 million/year based on an estimated annual average of seven newly constructed towers.

The near-term priorities of the Human Factors Research and Engineering Division are driven by the goals and objectives in *Flight Plan 2006-2010*. The *Flight Plan* is closely linked to the *Enterprise Architecture* that defines desired future systems and a transition strategy to the *Next Generation Air Transportation System Integrated Plan*. The enterprise architecture will establish the operational and technical framework for all capital assets of the FAA, and serves as the agency's basic investment strategy. The *Next Generation Plan*, managed by the Joint Planning and Development Office, is an ambitious approach that will enable the FAA to capitalize on tight federal R&D investments and achieve the national vision of a transformed aviation system.

We are at a strategic inflection point in human factors research. The convergence of decreasing resources, combined with *Flight Plan, Enterprise Architecture, and Next Generation Plan* demands, and a shifting landscape of technology and human performance capabilities and needs have created a fundamentally new research equation. ATO-P R&D is strongly positioned to succeed in this environment. We have a robust research portfolio that has been tested. We are committed to achieving and maintaining world-class levels of human factors research and fiscal discipline. We are leveraging technology to respond to near-term requirements, and are developing promising new products for the long term. We are continuing to build on our efforts to be a partner of choice for human factors research.

Even with sound strategies and a clear focus, the critical factor for success is having the right people in the right positions doing the right things. ATO-P R&D managers and researchers

performed superbly in 2005, and we are continuing to enhance the capabilities and commitment of our work force.

We look forward to the opportunities we face in the coming year to deliver human factors research and products that will improve the safety of aviation.

Paul Krois
Acting Program Director
ATO-P R&D Human Factors Research and Engineering

A New Equation

Transforming Human Factors to the Years 2010, 2015, 2025

This is our fourth Technical Program Review on FAA human factors research. As we look back over those years, we can see significant achievements by all our program managers and researchers. For example, our Web page has matured, and now includes the Human Factors Workbench, which assembles in one easy to use location the most-needed information for practitioners, researchers, and managers in the human factors community. Early versions of the Human Factors Certification Job Aid addressed only Part 25 Transport Category Aircraft displays, controls, and integrated flight deck systems such as the flight management system. Now in version 6.0, the Job Aid has expanded to include human factors summaries of Part 23 Commuter Category Aircraft Regulations and Advisory Circulars for human factors considerations related to displays, controls, and integrated flight deck systems.

Each year, numerous special training sessions are conducted by the air carriers to train pilots for newly identified, safety critical maneuvers and operations. Yet, at the same time, researchers have found that this type of event-specific training doesn't prepare pilots for all possible eventualities. Instead, pilots need to be prepared to react flexibly and creatively to new, previously unseen events. Intense research over the past three years has resulted in new methods for air carriers to develop training curricula that will prepare pilots for unexpected operational events such as an abnormal or emergency condition. This research addresses the psychological, cognitive and behavioral processes contributing to surprise, and identifies factors underlying events perceived as abnormal or emergency.

For several years, FAA researchers have been working to develop a web-based surveillance and auditing tool (WebSAT) that will provide a standardized format for maintenance data collection, reduction and analysis to identify factors contributing to maintenance errors. The goal of this research is to reduce errors and improve the reliability of aircraft inspection operations. WebSAT will provide the capability to standardize the data collection process supporting analysis of maintenance errors prior to aircraft dispatch. This will also facilitate analysis of trends across airlines.

Our researchers continue to examine ways to present and integrate information, to measure controller operations, and to ensure human factors considerations are taken into account in developing the controller workstation of the future. In one of the most complex person-in-the-loop simulation studies ever conducted at the FAA's William J. Hughes Technical Center, researchers exposed controllers to three new workstation concepts and three levels of traffic. The

results of this research project will ultimately help to calibrate how the design of user-centered automation increases controller productivity and enables the air traffic system to increase capacity.

With the forecast of continued increases in aircraft passenger traffic, and with the arrival of new regional, long-distance, and high passenger volume aircraft, aircraft cabin evacuation research is critical to the certification process. Because real-life certification tests for passenger cabin evacuations are expensive and dangerous, the test is usually limited to a single event under fixed conditions. Actual accidents may result in a variety of damage conditions that affect cabin evacuation. FAA researchers have now developed a computational aircraft evacuation model that uses features such as the shortest distance to exits, speed of an evacuation cue line, gaps in the evacuation cue line, and flow rate at exits. It has evacuees cut in front of one another in a cue, move to a different exit if the line is moving too slow, and engage in other behaviors characteristic of aircraft evacuations. Researchers applied the model to several aircraft, including the Airbus 320 and 380 and the Boeing 767 and 777. With further development and validation, the model may be used to improve training strategies to enhance passenger survival rates in the event of an accident.

Today we are responding to the new aviation equation by leveraging our strengths: high impact human factors research; a commitment to safety; the application of technology to maximize the value of our resources and to develop promising new areas of research; and the creation of partnerships that benefit the Federal Aviation Administration, the aviation community, and, most importantly, the flying public. As you read through the pages that follow, you will begin to see how our successes in 2005 strongly position us to succeed in the evolving environments of 2010, 2015, and 2025.

The Human Factors Research Team

Front row, left to right: Glen Hewitt, Jennifer Gooden, William "Kip" Krebs
Back row, left to right: Paul Krois, Tom McCloy, Larry Cole, Charles Overbey, Dino Piccione

Not shown: Eleana Edens, Carolyn Williams

Strategy + Execution = Sustained Results
In 2005, we achieved milestones that are delivering strong results now and will continue to produce into 2010, 2015, and 2025. Listed below are our top projects for all program areas.

Air Transportation Human Factors

Air transportation human factors research and products are enhancing the safety of the National Airspace System through improved pilot training and safety data collection and analysis. Program manager Dr. Eleana Edens directs research that provides methods and guidance for effective pilot training as well as valid and reliable assessment of pilots and their training. The research also provides methods for airlines to collect and analyze different sources of operational safety-related information.

To be successful and provide valuable products to industry and the FAA, this research must consider distinct segments of aviation systems. Individuals comprising the crew, instructors who train and evaluate crews in the classroom, simulator, and airplane, line operations personnel, and the management culture responsible for air carrier safety are all areas of high interest. Researchers are studying the variables important to Line-Oriented Flight Training (LOFT) and Line-Oriented Evaluation (LOE) development, implementation and evaluation. This research focuses on: (a) LOFT/LOE development strategies; (b) instructor training and evaluation; and (c) organizational and systematic influences on pilot performance, including the use of flight deck automation. In conducting this research, many sources of data are considered. Included is data from airline simulator sessions, airline flight deck observations, and traditional laboratory studies. The research examines methods to enhance the reliable and valid collection of operational safety data by providing taxonomies that incorporate human factors components of every-day airline incidents. This allows airlines to accumulate data that can be systematically analyzed to determine safety threats.

Developing Flight Safety Data Collection and Analysis Systems

FAA Sponsor Organization: AFS-230

Purpose and Rationale: The purpose of this project was to develop the Aviation Causal Contributors for Event Reporting Systems (ACCERS), a taxonomy for classifying human factors issues that are identified as primary or contributing causes in Aviation Safety Action Program (ASAP) incident reports. Although several coding systems already exist, detailed information concerning their development and psychometric properties was largely unavailable. The data that were available suggested that no taxonomy met all the requirements of a sound classification system or fulfilled the needs of the FAA for a way to categorize ASAP data. The research team employed a combination of data-driven and theory-driven methods to create ACCERS, a flexible, inclusive taxonomy of causal contributors to human error in aviation. The taxonomy is complete, and has been embedded into IFQASys, a web-based electronic data collection and reporting tool that provides sophisticated query and data analysis capabilities, thus allowing carriers to develop data-driven interventions and empirically assess their effectiveness.

Methodology: In FY 2003, researchers completed a review of existing human factors taxonomies, accident/incident reporting systems, and data collection tools. This provided a list of approximately 300 commonly used contributors to human error in aviation. FY 2004 tasks focused on using these factors as the basis for developing and testing a taxonomy with pilots. During FY 2005, data collected during the usability tests conducted in FY 2004 was analyzed, final changes were made to the taxonomy, category and factor definitions were completed, ACCERS was embedded into IFQASys, and a technical report was prepared.

Results: Data analysis from two rounds of usability tests was completed. Results suggest agreement among subject matter experts (SMEs) was higher at the general category level than at the more specific factor level. Agreement indices also showed that pilots had difficulty separating process issues from outcome issues. A recommendation was made to remove the outcome category and factors from ACCERS and ask pilots to identify the outcome in a different section of ASAP, forcing them to think about outcome and process separately. Researchers also prepared a list of definitions at the factor level.

Recent Accomplishments: Version 1.0 of ACCERS, which is a taxonomy that incorporates the best of science and "real-world" practicality, is complete. ACCERS yielded a document that illustrates the seven high-level causal contributors to human error in aviation, and shows the hierarchical assignment of an additional 70 detailed factors to these seven categories. Definitions are provided both at the category and factor level. ACCERS has been transitioned into IFQASys, an online ASAP reporting system that is currently being implemented at 20 airlines. Researchers are currently collecting pilot test data on taxonomy assignments. The final project technical report was written and submitted. The team is planning research to transition ACCERS into ASAP reporting programs for dispatchers, with additional future plans to transition the taxonomy to flight attendants. A codebook for ACCERS is also planned, which will contain information for managers and users regarding how ACCERS was developed. Training guidance will be included to help both managers and users to best utilize ACCERS.

Primary Investigator: David P. Baker, American Institutes for Research

Managing Operating Documents and Aviation Information Management

FAA Sponsor Organization: AFS-230

Purpose and Rationale: With the increasing use of Electronic Flight Bags (EFBs) in commercial aviation, it is essential to determine best practices and optimum training for the management of electronic flight operations information. Working with an operator in the process of assessing EFBs has provided data on the entire EFB system including the hardware, software, instructor and crew training, changes to operational procedures, and implementation issues.

Methodology: Two key areas were analyzed in the implementation of flight deck information systems. The first area is the standardization of instructors as they assess the effects of an EFB on crew performance. Several Subject Matter Experts (SMEs) worked with researchers to develop behavioral markers to rate specific crew behaviors within key phases of flight. Those SMEs were trained in the use of the behavioral markers and were then assessed using some of the measures developed in earlier FAA sponsored research on inter-rater reliability (IRR). That process has been analyzed to identify areas where the IRR process needs improved instructor training materials and procedures with an emphasis on EFB related crew behaviors. The second area is the effects of the EFB and its training on crew performance. Crew performance data from 20 crews, half working with paper and the other half working with electronic documents, have been analyzed to determine areas where crew performance has been improved as well as areas where additional improvements are possible.

Results/Recent Accomplishment: All nine performance ratings showed better crew performance by those using the EFB. The ratings for Climb FMS usage, Clearance Change SOP, and Taxi-In SOP were significantly higher for crews working with the EFB compared with those working with paper documents. Results suggest areas where crew performance could be further improved through the training of best practices and the refinement of procedures. Those areas include preflighting the FMS and the use of electronic documentation in resolving abnormal situations.
The data indicated that with the appropriate development of standards and training, EFB systems can enhance pilot performance. Such standardization can also improve the efficiency of the FAA approval process for EFBs.

Primary Investigators: Barbara Kanki, NASA-Ames Research Center; Thomas Seamster, Cognitive & Human Factors

A Situational Approach to Flight Crew Training

Sponsor Organization: AFS-230.

Purpose and Rationale: Although the need for integrated Crew Resource Management (CRM) and technical training has long been recognized, the means by which this integration should be accomplished remains illusive. The current project has the objective of creating a conceptual framework within which CRM and technical contributions to the flying job can be meaningfully positioned. It is argued that true integration requires that CRM be defined and trained within a situational context that enables flight crews to learn to recognize the consequences of situational factors for achieving flight goals, and to utilize cognitive and CRM skills to effectively manage and resolve each flight situation. Training curricula built from sets of events that embody specific flight challenges provide a situational context for integrated skill acquisition and practice.

Methodology: The creation of a situational framework for integrated CRM and technical training requires the completion of three activities:

- *Identify Situational Factors* by analyzing each phase of flight and maneuver to identify the key factors that must be effectively managed.
- *Develop a Metacognitive Model of Crew Functioning* that supports the integration of situational and human performance factors within a common framework.
- *Create an Event Catalog*, with each event supporting links to both the situational factors identified in Activity One and the metacognitive model developed in Activity Two.

Results/Recent Accomplishment: The identification of situational factors was addressed in work accomplished during FY 2004. The major focus of FY 2005 research was creation of a metacognitive model of crew functioning. This model provides a common framework within which situational and human performance factors can be coherently integrated. The major product of this model is "situational semantics" that can be used to describe the meaning of a flight occurrence in terms of the problems and challenges posed by that situation. The crew's effectiveness in accurately making sense of the situation is reflected in their ability to utilize situational resources to manage situational risks and constraints.

This situational semantics takes the form of a set of themes. Each theme identifies one or a few challenges posed by a specific maneuver. A situational challenge reflects the major cognitive and CRM demands of that maneuver. The resulting set of themes constitutes the set of challenges that could be faced by a crew during line operations and, therefore, serves as the skeletal structure for an integrated CRM and technical curriculum. One or more sets of conditions can be identified for each theme, each set serving to explicitly define the conditional variables that embody the challenges posed by the theme. The theme and its condition sets define one or more events. The events provide important opportunities for crews to practice the strategies required to meet the challenges posed by that theme through the integrated application of CRM and technical skills required for effective situational management.

Primary Investigator: Susan Mangold, Battelle Memorial Institute

Analysis of Pilot Procedures and Practices for Automated Flight Decks

FAA Sponsor Organization: AFS-230

Purpose and Rationale: Automation has introduced changes to the forms of crew interaction in the cockpit. Although designers hoped that these changes would reduce errors, evidence suggests that this has not been the case. This leads to the question of how we might improve the performance of crews using automated cockpit systems. One approach is to design training and cockpit procedures with automated systems in mind. This research project is concerned with understanding the dynamics of crew-automation interactions in order to improve systems and systems safety.

Methodology: The goal of this research program is to assess current problems with automated systems on the flight deck and develop potential solutions to these problems as well as those generated by new systems. Researchers have taken three approaches to this issue. In the first project, they completed an analysis of data concerning how pilots perceive the safety of the monitored approach in low visibility conditions. In a second project, they are developing and implementing a new training program that will reduce training time and improve learning (knowledge about the automatic flight and flight management systems) and performance using the system. In the third project, they are evaluating a new interface, developed by Boeing, for the automatic flight system. Performance data have been collected from commercial pilots using a traditional autoflight panel and the new proposed autoflight panel.

Results: Over the past year, final data analysis has been completed and a report has been prepared on the monitored approach study. In addition, the research team developed an initial training scenario for a new training program for a regional airline, and completed data collection on performance of pilots using a new autoflight system. The monitored approach study provided recommendations that will be forwarded back to the NTSB in response to their request for study of this issue. If successful, the training programs developed for the regional carrier will lead to a revision of their training program for the future.

Recent Accomplishments: A report on the pilot monitored approach has been accepted for publication; researchers have reconnected with a regional carrier to allow for data collection; training materials for testing of the new prototype autoflight system have been developed; and, human performance data on this system has been collected.

Primary Investigator: Deborah A. Boehm-Davis, George Mason University

Boeing-FDF Prototype (Rendered using the Dynamic Storyboarding Tool - DST)

Automation Training Research: Mixed-Fleet Flying of 777 and 767-400

FAA Sponsor Organization: AFS-230

Purpose and Rationale: A study was completed that assessed the safety vulnerabilities that could be associated with mixed-fleet flying of the Boeing 777 and 767-400. The study was meant to provide objective data to make a decision from the perspective of all interested parties as to the requirements and constraints that may result from an airline choosing to fly the two airplanes as one fleet with the same pool of pilots. The two primary topics of investigation included examining the possibility of pilots making errors in one of the airplanes because of their experience with the other airplane, and the likely degradation of pilot skill in flying one of the airplanes if it had not been flown for up to six months.

Methodology: Research Integrations, Inc., an air carrier, the Airline Pilots Association, and industry were all involved in the design of the study and the interpretation of results. The study was conducted in two parts. First, a human factors vulnerability analysis was conducted to identify possible tasks that could result in pilot error when mixing the two airplanes. This part of the study resulted in a list of vulnerabilities based on analysis that would need to be validated with operational data. The second part was a longitudinal study in which 40 of the airlines pilots participated by performing particular tasks in the simulators. Half of the pilots currently flew the 777 and the other half the 767-400. None of the pilots had ever flown the other airplane. The pilots were given an evaluation in the simulator on their current airplane as the first element of the study. They then participated in an abbreviated training program in the new airplane, and upon completion, were give the same simulator evaluation in the new airplane. The pilots all went back to flying the line in their current airplane. Half of them were brought in for another evaluation on the new airplane at three months, and all of them came back in for the simulator evaluation at six months.

Results/Recent Accomplishments: The study resulted in one safety concern in mixing the two airplanes. This was related to the design of Takeoff/Go-Around (TOGA) switches: the 767-400 has a TOGA switch on both the fore and aft of the thrust levers that can be activated with either the thumb or fingers of the hand controlling the thrust. The 777 has the switch only on the forward side of the thrust levers. It was shown that the response times for accomplishing a missed approach at minimums and a rejected landing at about 100 feet AGL could be significantly slower if the pilots were inclined to initiate TOGA using the aft lever when it was not there on the 777. The study team recommended that this safety concern could be addressed with a design change by making the 777 TOGA switches similar to those on the 767-400. Other findings showed that several procedural and training items need to be addressed to effectively mix the airplanes, and that for most of the operations and maneuvers that were tested, a six-month currency cycle is acceptable.

Primary Investigator: Beth Lyall, Research Integrations, Inc.

Pilot Training for Unexpected Events

FAA Sponsor Organization: AFS-230

Purpose and Rationale: Current research seeks to identify the global, underlying skills needed by pilots to best respond to a myriad of unexpected events. Researchers are investigating alternatives and modifications to traditional training approaches, targeting these skills, and developing ways to augment the pilots' ability to respond to an unexpected event and any resultant consequences of that event.

Methodology: In a collaborative effort, researchers at the FAA and the University of Central Florida are investigating factors influencing pilots' reactions to unexpected events. They developed a theoretical framework that identifies key concepts related to the occurrence of and training for unexpected events. Work under this thrust is conducted in close collaboration with the University of New Mexico and in coordination with NASA-Ames Research Center and the Calspan Corporation.

Results: As a result of their work, researchers have recommended development of training interventions to manage unexpected events, such as scenario-based training, meta-cognitive training, and adaptive expertise training. These interventions will be prototyped and tested in upcoming years.

Recent Accomplishment: In FY 2005, researchers completed four studies on unexpected events. In the first study, a database review was conducted to determine which factors, or combination of factors, play a part in creating an unwanted outcome due to surprising or unexpected occurrences. The most important finding from this study was that any factor or combination of factors can potentially create a surprising or unexpected event that leads to an unwanted event, such as an abnormal or emergency condition. The second study was an in-person survey of pilots constructed to ascertain pilots' perceptions of unexpected events. Analysis of the survey data revealed that when pilots were asked directly what was most surprising to them, they were likely to respond with events that are overtly conspicuous, such as engine failure and thunderstorm encounter, but that they have a difficult time describing unexpected events with insidious onset. Together, these studies supported the notion that too much emphasis is given in current pilot training to catastrophic and emergency events, and too little attention is paid to the "normal" events that frequently become emergencies when timely responses are lacking.

The third study investigated how different aspects of expertise affected one's ability to detect and react to an unexpected event. Researchers explored how good judgment might influence the process of surprise at different stages and in different ways than would domain expertise. Study results indicated that general judgment skills were significantly associated with pilot performance in unexpected events, whereas domain expertise (measured both through traditional metrics, such as flight time, and through knowledge tests) was not.

Primary Investigator: Florian Jentsch, University of Central Florida, Orlando, Florida

Improving the Training of Automated Flight Deck Skills

FAA Sponsor Organization: AFS-230

Purpose and Rationale: This research seeks to determine if there are accurate and cost-effective alternative training and evaluation methods to measure a pilot's knowledge of automation as well as the skills required to fly today's modern automated aircraft. Options such as card sorting and concept mapping are examples of concepts that are being considered to replace traditional methods such as written exams and oral evaluations.

Methodology: The human factors research team created a new software tool, Team Performance Laboratory Knowledge Assessment Tool Set (TPL-KATS), for assessing complex knowledge structures and mental models necessary for the operation of advanced transport category aircraft. Researchers are using this tool to evaluate pilot automation training. The goal of the project is to develop a system that will allow evaluators to diagnose problem areas within knowledge structures based on the mental models being represented. Work under this thrust is conducted in close collaboration and coordination with George Mason University and Research Integrations, Inc.

Results: In cooperation with several airlines, researchers are examining the capabilities of the TPL-KATS to evaluate pilots' knowledge of automation. These investigations yielded results that show the concept mapping and card sorting techniques are comparable to traditional testing methods. Multiple studies have shown that card sorting and concept mapping can be (a) reliable, (b) valid, and (c) predictive indicators of auto-flight knowledge.

Recent Accomplishment: In FY 2005, researchers used the TPL-KATS tool to collect longitudinal data from pilots going through initial training in an automated aircraft at a major air carrier and at a regional airline. The goal has been to study tools and methods that best represent a pilot's knowledge of the Flight Management System (FMS). Specifically, the team has been investigating use of the conceptual knowledge elicitation technique, concept mapping. The findings have shown that concept mapping is capable of predicting performance on a procedural task within an academic setting, and is likely to predict how well a pilot will perform when interacting with the FMS. Data have been analyzed and presented at several professional meetings, including the International Symposium on Aviation Psychology, the Human/Computer Interaction International conference, and the annual meeting of the Human Factors and Ergonomics Society.

Primary Investigator: Florian Jentsch, University of Central Florida, Orlando, Florida

Human Factors of Notices to Airmen (NOTAMs)

FAA Sponsor Organization: AFS-230

Purpose and Rationale: Notices to Airmen (NOTAMs) are temporary notices that contain important time-critical information that pilots need in order to make informed decisions when planning flights. These notices provide information such as airport closures, airspace restrictions, and closed runways. This NOTAM project analyzed the human factors aspects of the NOTAM system to determine how pilots can obtain the most useful information from the system, and assessed whether changes might lead to substantial performance improvements.

Methodology: Researchers distributed a survey to 79 pilots, who revealed that it is easy to make mistakes using the NOTAM system, and that NOTAMs can be easily misinterpreted. Furthermore, pilots suggested that ways to improve the system include the use of plain language, creating a single source from which all NOTAMs can be obtained, and better organization of the NOTAMs.

Results: This project resulted in a technical report highlighting the issues of concern with the current NOTAM system and providing suggestions for possible improvements to the system, locally, nationally, and internationally.

Recent Accomplishment: In FY 2005, UCF researchers published research findings in *The International Journal of Aviation Psychology*. These findings highlighted recommended improvements to the NOTAM system. These recommendations should make it easier for the readership to understand the intricacies pertaining to the NOTAM system. Human factors researchers are also part of a NOTAM task force by the plain language coordinator at the FAA Office of the Administrator.

Primary Investigator: Florian Jentsch, University of Central Florida, Orlando, Florida

Training and Assessing Aircrew Skills:
Methods to Achieve Reliable and Valid Performance Data

Purpose and Rationale: The purpose of this research is to develop and validate methods for improving the training and evaluation of pilot performance. Specific research goals this past year included (a) investigating the effects of expectancy on skill acquisition and decay, and (b) developing methods for analyzing large corpuses of flight accident and incident reports to support ASAP programs. A critical aspect of flight training is to develop pilot skills for unexpected events such as emergency situations. The goal is to better understand how differing levels of expectancy affect performance on these types of skills. The results of this effort may suggest changes in how pilots are trained and assessed on maneuvers that occur infrequently. Flight incident and accident reports (e.g., ASRS, ASAP) are widely viewed by the aviation community as containing valuable flight safety information. Such information will likely influence the direction of training and evaluation of pilots. A goal was established to develop a set of methods that will allow an analyst to examine a large corpus of narrative text within accident and incident reports. These methods will support exploring the relevance of particular topics within a corpus of text and aid in uncovering emerging trends in flight safety.

Methodology: Researchers are using a PC-based flight simulator to explore the question of expectancy on skill decay. After students are trained on a limited set of maneuvers (e.g., normal and rejected takeoffs), the team is able to systematically manipulate the degree of expectancy for an abnormal maneuver (e.g., rejected takeoff) by altering its probability of occurrence over a sequence of trials. They can then compare performance across differing levels of expectancy and when skill decay is found, methods for reducing it can be investigated. PC-based software for the analysis of flight incident and accident reports has now been developed. The approach is to use Latent Semantic Analysis (LSA) to extract higher-order information contained in the narrative text of flight-safety reports. LSA is based on singular value decomposition (SVD), a method widely used in the text analysis research to extract higher-order semantic information from a large corpus of text.

Results: A series of laboratory experiments investigating skill decay for unexpected events have been conducted. Researchers have established a training and testing protocol that reliably shows that performance on a rejected takeoff, as defined by reaction time to cut the throttles and deviation from runway centerline, is worse under conditions of low expectancy compared to a baseline measure of performance. A C code has been written to identify a set of relevant key terms, process large amounts of text information into standard term by document matrices, carry out various types of transformations on raw term frequencies, and perform singular value decomposition (SVD) on very large sparse matrices. In addition, a complete set of ASRS reports (available though NASA-Ames) has been acquired, and development of methods for identifying and categorizing the reports based on LSA information has started.

Recent Accomplishment: A principal accomplishment this past year has been the development of PC-based software to efficiently analyze a large corpus of text (thousands of terms by thousands of documents) using singular value decomposition.

Primary Investigators: Timothy E. Goldsmith, Peder Johnson, John Moulton, University of New Mexico

Computerized Generation of Simulation Scenarios with the RRLOS Tool

FAA Sponsor Organization: AFS-230

Purpose and Rationale: The human factors team developed the Rapidly Reconfigurable Line Operational Simulation/Evaluation (RRLOS/RRLOE) computerized scenario generation system for the FAA's Voluntary Safety Program Office. RRLOS allows training developers to combine training event sets and create training materials. It also generates scenario scripts in real time.

Methodology: Researchers have developed, tested, distributed, and updated software that allows training administrators to create scenarios which accurately, efficiently, and quickly evaluate pilot performance and training needs using a realistic set of events. Work under this thrust is conducted in coordination with the Volpe National Transportation Systems Center.

Results: Using the software, a two-hour training scenario can be generated in five to twenty-five minutes versus two to six weeks previously. The software can target specific skill areas, thereby allowing the quick generation of scenarios that are customized to the trainee and his/her training needs, and include customized training materials such as scenario scripts and supporting materials.

Recent Accomplishment: During FY 2005, RRLOE/RRLOS navigation data was continually updated for a select group of airports. Scenarios created with the tool reflect the latest changes to instrument flight procedures. Use of current navigation data allows for increased realism when utilizing RRLOE/RRLOS scenarios. The tool is currently being used by several airlines.

Primary Investigator: Clint Bowers, University of Central Florida, Orlando, Florida

Flight Simulator Fidelity Requirements Research

FAA Sponsor Organization: AFS-230

Transfer of training - aircraft to simulator, simulator to aircraft

Purpose and Rationale: The purpose of the project is to ensure that flight simulator qualification standards, which may soon become regulatory, are sufficient and necessary for effective, yet affordable equipment. Earlier work in the framework of this project examined the issue of simulating distractions stemming from radio communications between aircrew and entities outside the cockpit. Another line of inquiry studied the issue of simulating airplane motion during recurrent qualification of airline pilots. Presently, the focus has shifted to examining the effect of simulator platform motion on qualification of airline pilots undergoing initial training.

Methodology: Over 40 pilots were trained and tested on a Level D full-flight simulator (Boeing 717-200) after completion of ground school. Half were trained with motion, the other half without. To assess the effect of motion on transfer of training, all were then tested in the simulator with motion as a stand-in for the airplane. Data were collected from the simulator and with questionnaires.

Results/Recent Accomplishment: As with earlier studies examining the effect of motion on recurrent training and evaluation of airline pilots, preliminary results for this study of initial training did not support a conclusion that flight-simulator motion benefits training. The study did confirm that motion cues alert pilots of engine failures more effectively than visual cues alone, but the effect was again very small and this time only marginally significant. Most importantly, once pilots transferred to the simulator with motion, the pilots trained without motion responded as fast as the pilots trained with motion. The only other potentially beneficial effect of motion found with initial pilots was that the motion-trained pilots kept the column slightly steadier than the pilots trained without motion during both training and testing. This slightly improved their airspeed compliance, but did not lead to steadier pitch angle. When hand-flying an engine-out approach with shifting crosswinds, it was the pilots trained without motion that used a steadier control strategy (for pedal rather than column inputs) throughout, with no apparent effect on flight precision. The recurrent pilots trained without motion in an earlier study had also used a steadier control strategy than those trained with motion for this maneuver, but it had been for the wheel and it did result in higher flight precision. Finally, pilots showed no preference for either of the two conditions. As with recurrent pilots, there was no evidence that the conflicting stimulation of the visual and the vestibular systems induced discomfort in the no-motion condition.

Whether the overall statistical power of the experiment was sufficient to find all operationally relevant effects will need to be decided by the operators based on the smallest detectable effects listed in a technical report. Moreover, a few additional analyses need to be performed before

coming to final conclusions on this study. Nevertheless, it appears that this study found interesting effects that fit in well with the program's previous research on the effects of simulator platform motion.

Primary Investigator: Judith Bürki-Cohen, Volpe Center

Monitoring and Checklist Use in Normal Flight Operations

FAA Sponsor Organization: AFS-230

Purpose and Rationale: Crew monitoring and checklist use are essential defenses against diverse threats and against pilot error. These defenses have hidden weaknesses that have contributed to many airline accidents. By analyzing these hidden weaknesses, we can improve essential defenses and improve safety. Both the National Transportation Safety Board 12-year study of accidents attributed to crew error and NASA research reveal that breakdowns in monitoring and execution of checklists have played central roles in many, perhaps most, airline accidents. The air carrier industry requires data on how monitoring is performed, how checklists are typically used on the line, and data on the factors that impede effective execution of these critical procedures.

Methodology: The research team used jump seat observations to collect data on monitoring and on how normal checklists are routinely used.

Results: This is a pilot study to determine the feasibility of this type of analysis. To date, 22 flights involving two aircraft types at two airlines have been observed.

Recent Accomplishment: Preliminary observations reveal: (1) monitoring deteriorates during an unstabilized approach; (2) inappropriate reliance on altitude chime for altitude level-off: (3) failures to monitor autopilot level-off; (4) flow-then-check procedures sometimes devolving into read-and-do; (5) checklists sometimes performed from memory; and, (6) first officers sometimes head-down during critical phases of taxi (e.g., crossing runways).

Primary Investigator: Key Dismukes, NASA-Ames Research Center

Advancing Aviation Safety:
Threats, Errors, and their Management in Normal Operations

FAA Sponsor Organization: AFS-230

Purpose and Rationale: Human factors researchers are working to promote the use of Line Operations Safety Audits (LOSA) and the Threat and Error Management (TEM) framework throughout the aviation industry. It is envisioned that as the project provides more information and technical advice about TEM and LOSA to more and more sectors of the aviation industry, a common framework will emerge that allows personnel from different areas of an airline (safety, training, flight operations, dispatch, etc.) to identify and address common safety issues.

Methodology: In earlier work, researchers developed LOSA, a non-jeopardy cockpit observation methodology for monitoring normal operations. Based on the TEM framework, LOSA captures pilot performance and the operating context in which it occurs. Data collected from over 20 airlines are now housed in the LOSA Archive.

Results: The LOSA Archive contains data from more than 4,800 jump seat observations collected over the last five years. These data include 17,000 threats, 12,000 errors, and 2,000 undesired aircraft states, as well as detailed phase-of-flight narratives and ratings of crews' TEM countermeasure performance. Data-mining of the Archive has begun, with results expected shortly.

Recent Accomplishments: In the last year, researchers authored an Advisory Circular on LOSA, which is currently under review at the FAA. The researchers also made presentations at several major industry conferences. In addition, they supported development of a new observational methodology for ATC called the Normal Operations Safety Survey (NOSS). The ICAO-sponsored ATC working group used LOSA and the TEM taxonomies as a starting point for their methodology. In addition, the TEM/LOSA methodology has been adapted successfully to airline dispatch and ramp operations. This integrated approach means that safety initiatives throughout an airline have a common framework and can be integrated. ICAO and IATA have both endorsed and adopted the TEM concept and have endorsed LOSA as a critical safety initiative.

Primary Investigators: Dr. Robert L. Helmreich, The University of Texas, Austin, TX

Aviation Maintenance Research

Dr. William Krebs leads an Aviation Maintenance human factors research team that has the overall goal of identifying and optimizing factors that affect human performance in aviation maintenance and inspection. The focus is on the technician, but extends to the entire engineering and technical organization and to all personnel involved in the endeavor. Research attention to personnel can include selection, qualification, training, motivation, health, professionalism, and the variety of human capabilities and limitations that affect efficient and safe maintenance task performance. The research considers many aspects of the work environment, including both the physical and social aspects of the organization. The complexity of technical communication is an example of such research. The diversity of maintenance and inspection activity is unlimited. Thus, the research attends to each and every action performed by individuals, teams, departments, and the collective organization. With a view of people, the environment in which they work, and the actions they perform, a final focus is on the resources necessary for efficient and safe work. Research related to resources includes studies on the design of documentation and procedures, selection of tools, equipment, buildings, and applications of advanced technologies for maintenance and inspection. The aviation maintenance human factors research program combines critical basic scientific understanding of human performance with applied studies conducted in cooperation with industry and academic partners. The results are solid and proven science, psychology, and engineering, delivered in plans, procedures, software, and even hardware that can be immediately implemented to affect efficiency and safety.

An International Survey of Maintenance Human Factors Programs in Maintenance Organizations

FAA Sponsor Organization: Flight Standards Service, Aircraft Maintenance Division

Purpose and Rationale: The purpose of this study is to assess what airline maintenance companies have done, are doing or are planning to do regarding the human factors elements of Part 145. International outcomes will provide an opportunity to determine if voluntary versus regulatory approaches to the development of human factors programs for maintenance organizations has resulted in different approaches. While covering a number of areas, questions are focused around training, error management, fatigue management, and additional human factors metrics. Additionally, respondents will be asked to describe their organization's support of their human factors program. The goal of this effort is to identify areas of concern so that the FAA may affect corrections in FAA policy, guidance material, and FAA-sponsored programs in order to improve the overall quality of airline maintenance. A small survey of US maintenance organizations was conducted in 2002, as part of the Commercial Airplane Certification Process Study for Human Factors. This new proposed survey will provide an international comparison of the state of Human Factors in industry with the more limited national results found in 2002.

Methodology: Employees at specified international airline maintenance organizations will receive an electronic invitation to respond to the survey. With coordination from the European Aviation Safety Agency, several airlines, and FAA representatives, potential respondents will be identified. The respondents will be employed within the maintenance firms as engineers, quality assurance specialists, maintenance directors, and mechanics.

Results/Recent Accomplishments: An initial draft of the online questionnaire has been developed, using input from FAA personnel as well as national and international industry representatives. An electronic version of the questionnaire was administered to approximately 30 representatives from Europe, Asia, South America, and the U.S. for review and comment. Feedback will be used to make final adjustments to the instrument prior to submission to OMB. The Federal Registry announcement was submitted and the mandatory period of review has passed. Dr. Hackworth attended the JAA/EASA in October 2005 to discuss the survey's progress.

Primary Investigator Carla A. Hackworth, FAA Civil Aerospace Medical Institute, Oklahoma City, OK

Development of Guidelines and Tools for Effective Implementation of an Aviation Safety Action Program (ASAP) for Aircraft Maintenance Organizations

FAA Sponsor Organization: Flight Standards Service, Voluntary Safety Programs Branch

Purpose and Rationale: Aviation Safety Action Programs (ASAP) identify and correct adverse safety events that would otherwise not likely come to the attention of the FAA or company management. Prior to the start of this research project, there were twenty-eight airlines that operated ASAPs for pilots, but there were only six ASAPs for aircraft maintenance mechanics. Of the six maintenance ASAPs, most were considered by all stakeholders to be highly effective. Because of the potential benefits to safety, a major interest of the FAA was to determine whether the failure of ASAPs to expand to multiple operators as rapidly for aircraft maintenance as it had for pilots was attributable to FAA's ASAP policy, or to other factors beyond the control of the FAA. The first year of this project identified two key barriers to ASAP programs in maintenance organizations: lack of interpersonal trust between employees and management and lack of general awareness regarding the ASAP program.

Methodology: In the second year of this project, emphasis was placed on further defining the barriers, facilitating the transfer of best practices across maintenance organizations, and testing the capability of a text analysis system to aid in the analysis of ASAP reports. Saint Louis University participates as a resource to the newly formed Maintenance Subcommittee of the industry-wide ASAP/FOQA Aviation Rulemaking Committee. In this role, the researchers are better able to collect qualitative input from the maintenance community and connect the more successful ASAP programs with those that are struggling. A commercial off-the-shelf software called LexiQuest was used to test the potential benefits of incorporating computerized text analysis capability in ASAP programs.

Results: First, interpersonal trust and awareness are related. Therefore, industry groups such as the Maintenance Subcommittee (mentioned earlier) and appropriate labor organizations could make a significant contribution toward raising the awareness of maintenance-specific issues and enabling the transfer of best practices across organizational boundaries, including various FAA regional and field offices. As the awareness of the value and effects of an ASAP program increases, the trust in this program as well as among the people in charge of such a program is bound to increase. Second, initial tests of the text analysis system indicate that such analysis could uncover deeply hidden systemic hazards that would not be detectable by the conventional error classification systems. A hybrid system that incorporates the advantages of both structured as well as unstructured techniques would be invaluable. Third, efforts are underway to prepare the maintenance community to participate in the industry-wide Voluntary Aviation Safety Information-Sharing Process (VASIP) effort.

Recent Accomplishment: This research project serves as a resource to the Maintenance Subcommittee—the key industry group that will provide a comprehensive feedback to the FAA regarding maintenance ASAP programs. Further, this subcommittee, in partnership with the researchers, will seek to bring multiple air carriers and repair stations to participate in industry-wide data sharing.

Primary Investigator: Manoj S. Patankar, Saint Louis University, St. Louis, MO

Effects of Fatigue/Vigilance/Environment on Inspectors Performing Fluorescent Penetrant and/or Magnetic Particle Inspection

FAA Sponsor Organization: Flight Standards Service, Aircraft Maintenance Division

Purpose and Rationale: Recent accidents have emphasized the importance of inspection reliability to aviation safety. One key aspect of reliability is the effect of long, continuous working times of inspectors. Extended time periods could cause a vigilance decrement and/or fatigue in inspectors, leading to reduced defect detection performance. This may be particularly apparent under conditions of highly repetitive tasks and darkened conditions, typical of fluorescent penetrant and magnetic particle inspection tasks. Researchers at University at Buffalo: SUNY are seeking evidence as to whether this phenomenon exists for fluorescent penetrant inspection (FPI) or magnetic particle inspection (MPI).

Methodology: A number of site visits were used to address environmental and temporal conditions of inspection, and collect survey data on hours of work. In support of the behavioral experiment, a computer program for simulating FPI inspection has been written, tested and validated. The program uses six views of each of 63 high-quality photograph engine blades, a comprehensive data collection facility and a good navigational interface. A six-factor screening experiment was used to measure probabilities of detection (PoD) and false alarm (PoFA), plus time taken per item (throughput). The one- or two-hour task was performed in day and night times, with or without breaks, in light and dark conditions and with different types and probabilities of defects. Mental workload of inspectors and sleepiness are measured. Any significant factors or interactions will be explored further in a series of parametric experiments.

Results: The factorial experiment was completed using 80 local recruits with industrial experience, specially trained for the simulation task. Results showed the expected significant individual differences and their interactions with some variables, e.g. Day/Night. Thus, night working may affect inspectors differentially, so that not all may be suitable for Night work. Across a quite long period of continuous inspection (up to two hours), performance measured by PoD may change differentially with Day/Night, but the other dependant variables, PoFA and speed measures, all appear to improve with Time on Task. Any vigilance decrement may be limited to Night conditions. In this combined search and decision task (Drury, 2001), with performance times measured in minutes rather than milliseconds per blade, vigilance decrement does not appear at the same magnitude as in typical laboratory vigilance tasks (e.g. Parasuraman and Davis, 1977). Horowitz et al (2003) have already reported that the search function may not show the classic vigilance decrement phenomenon shown by primarily decision tasks. There appeared to be interesting effects of working in light conditions vs. dark conditions, where the best condition for throughput was the one with the best match to the outside light levels, i.e. Day vs. Night. This may have practical implications for setting light levels in FPI inspection, which is always carried out at low levels to illumination so as to be able to view the fluorescence under UV lighting.

Recent Accomplishment: Completion of running and analysis of 80 participants in the initial factorial experiment. This allows parametric experiments to be designed to explore significant interactions in more detail, leading to more detailed recommendations for reducing fatigue effects in repetitive inspection

Primary Investigator: Colin G. Drury, University at Buffalo: SUNY, Amherst, NY

Use of Advanced Technology to Support Inspection Training in the General Aviation Industry

FAA Sponsor Organization: Flight Standards Service, Aircraft Maintenance Division

Purpose and Rationale: Since standards for inspector training in the General Aviation industry area, for the most part, nonexistent, various GA maintenance facilities have developed their own inspection training programs. These initiatives, which tend to be ad-hoc, incomplete, and inconsistent in their level of detail, do not follow good human factors principles of training design. This situation suggests that a comprehensive off-line inspection training program, which systematizes the training process, draws upon good principles of inspection training and exposes the trainee to various simulated inspection situations, can play a role in improving performance. Thus, the general objective of this research is to demonstrate how advanced technology can be used for visual inspection training to reduce inspector errors. Its specific objective is to develop and deliver a computer-based inspection training system entitled the General Aviation Inspection Training System (GAITS). Designed for training aircraft maintenance technicians in inspection skills, this tool uses a multi-media presentational approach, including a low fidelity inspection simulator.

Methodology: This research utilized an integrated task analytic and iterative software development methodology, its underlying motivation being to improve inspection performance via the development of training programs based on task analyses of the existing environment. The first step used task analyses to identify factors affecting aircraft inspection performance and, subsequently, using these, developed a framework to understand inspection performance. Based on this framework, intervention strategies were identified to reduce their negative consequences. Next, the investigative team identified which of these strategies can be most impacted by training. Following this step, the GAITS training program was developed using the classic iterative development methodology.

Results: This research extends work from the past several years into a functional prototype computer-based training system called the General Aviation Inspection Training System (GAITS). In 2005, the research team developed and organized material from the previous year into an inspection training program consisting of the five modules of introduction, training, simulation, design and analysis. The specific activities conducted in support of the development of GAITS included the following: (1) the development and evaluation of alternate interfaces, (2) the development of scripts and storyboards, the script specifying the text, the computer-based graphics, the simulations and the audio content to be used and the storyboards depicting the individual frames showing the specific content of the scripts for a single module. (3) the computer coding of the individual modules and (4) the testing of the modules.

Recent Accomplishment: Developed prototype GA maintenance training system.

Primary Investigator: Anand K. Gramopadhye, Clemson University, S.C.

Do Language Barriers Result in Maintenance Deficiencies?

FAA Sponsor Organization: Flight Standards Service, Aircraft Maintenance Division

Purpose and Rationale: Contract maintenance is a preferred corporate strategy for reducing nonessential costs and focusing an organization on its core business. In aviation maintenance, this strategy has been advocated and widely used, as it avoids tying up capital in maintenance facilities, and can reduce costs by opening the airline's maintenance operation to outside competition. One potential impact of such contract maintenance is that there are more interfaces within the system, each of which represents an opportunity for error. The existence of maintenance and inspection personnel whose native language is not English suggests that language barriers may be causing performance errors. This project examined whether such errors exist, what patterns characterize these errors, what their contributing factors are and how effectively we can mitigate these errors.

Methodology: Language errors can be characterized as communication errors by definition. The first step in this research was a review of models of communication to search for characteristic error patterns. Seven error patterns were found from focus groups and used to estimate incidence of language errors across 941 AMTs, inspectors and engineers at MROs on four continents using English, Chinese and Spanish as native languages. In addition a task card comprehension study was used to measure intervention effectiveness on the same sample, with interventions consisting of AECMA Simplified English, a glossary, a bilingual coach and two forms of document translation. Focus groups at each site examined current best practices.

Results: Scenario incidence and intervention effectiveness data were collected on 941 participants in China, Hong Kong, Taiwan, Columbia, Mexico, Puerto Rico, Argentina, Spain and the USA. All seven scenarios were found to be well-supported in all regions. Three scenarios gave high frequencies, inadequate verbal and written communication abilities of AMTs, and a supervisor not realizing that the AMT had difficulty with English. All had frequencies estimated by participants at 4-6 times per year. There was a consistent group of four factors highly related to the scenarios: (1) The AMT or inspector has inadequate written English ability, (2) The AMT or inspector has inadequate verbal English ability, (3) The task instructions are complex, and (4) Time pressure makes the AMT or inspector hurry. For intervention effectiveness, there was again agreement across the regions. Analysis of variance in each region, and a Friedman test between regions showed that only translation (partial or full) was a significant factor affecting speed and accuracy, while a significant covariate was the reading grade level of the AMT. The USA had consistently the highest accuracy and lowest time. For the baseline condition, the "best" country or area in each region was the one where bilingualism was the norm: Hong Kong and Puerto Rico. The one European country, Spain, had good performance compared to other Spanish speaking countries. Reading levels for AMTs were about 5th grade in most regions, about 6th grade or better in bilingual countries and about 14 in the USA.

Recent Accomplishment: Data from 941 participants provides the most complete picture yet of language error in maintenance. Two recommendations have been made: either use translation of documents (partial or full) or provide aviation-specific training to all who use English documentation.

Primary Investigator: Colin G. Drury, University at Buffalo: SUNY, Amherst, NY

Human Factors in the Maintenance of Unmanned Aircraft

FAA Sponsor Organization: Flight Standards Service, Aircraft Maintenance Division

Purpose and Rationale: The human operator is still a critical element in the maintenance and flight of unmanned aircraft. It is anticipated that human error will pose a threat to the operation of UAVs, just as it does in other fields of aviation. The Federal Aviation Administration must understand the human factors issues of unmanned aircraft to ensure that safe operations occur in the National Airspace System.

The objective of this task is to identify human factors issues related to UAVs that will need to be addressed by the FAA for incorporation into SFAR documents. The requirements include, but are not limited to, maintenance tasks unique to unmanned aircraft systems, knowledge and skill requirements for UAV technicians, and challenges in the maintenance of UAV systems.

Methodology: Structured interviews were conducted with 22 UAV users from commercial and military operations. Interviewees were asked a series of questions designed to reveal human factor issues associated with UAV maintenance. In addition, site visits were conducted at selected UAV maintenance facilities. A distinction was made between manufacturers who fly and maintain their UAVs, and customers who purchased UAVs. Of the sample group, 36% were manufacturers and operators of their own UAVs.

Results: Twenty-three issues were identified on the basis of interviews. Issues were grouped into three categories: hardware; software/documentation; and personnel issues. Hardware issues included the frequent assembly and disassembly of systems, and a lack of information on component failure patterns that would enable maintenance to be planned effectively. Software and documentation issues included the need to maintain computer systems, and difficulties associated with absent or poor maintenance documentation. The last class of issues deals with personnel issues including the skill levels of maintenance staff.

Recent Accomplishment: A key difference between the maintenance of conventional aircraft and UAV maintenance is that the latter requires attention not just to the aircraft, but to the entire system including the ground control station, wireless communication links, sense-and-avoid instrumentation, and, in some cases, specialized launch and recovery equipment. The importance of maintaining computer control systems and wireless communication are the main challenges that are unique to UAVs.

Primary Investigators: Stanley Herwitz, UAV Collaborative Center, NASA Research Park, Moffett Field, CA & Alan Hobbs, SJSU Foundation, NASA Ames Research Center, Moffett Field, CA

Development of a Web-Based Surveillance and Auditing Tool (WEBSAT) To Analyze Aircraft Maintenance Operations

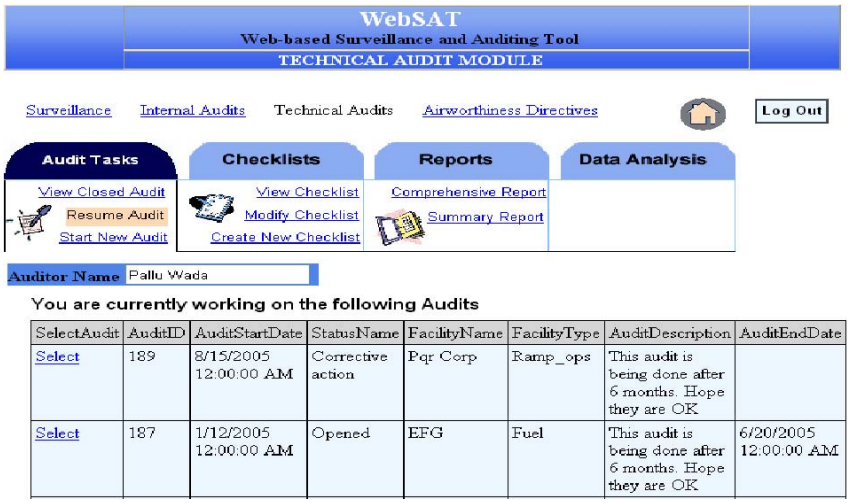
FAA Sponsor Organization: Flight Standards Service, Aircraft Maintenance Division

Purpose and Rationale: Safety being the primary concern of the aviation industry, it is imperative that effective data analysis be conducted on data obtained from various aviation maintenance processes. The systematic evaluation of data collected on these maintenance processes can provide feedback on the performance of an airline and proactively support the decision-making process prior to the dispatch of the aircraft. WebSAT is a tool which is intended to capture errors from aviation maintenance processes and analyze the data in a standardized fashion to further evaluate the effectiveness of each of these maintenance processes. WebSAT will collect and analyze data for the quality assurance work functions of aircraft maintenance, which are surveillance, internal audits, technical audits, and airworthiness directives. Given the different scenarios that are presented to each user, based on their requirements, the design of the system plays a vital role in the accomplishment of the users' goals. This research focuses on the product design methodology used to prototype the technical audits (TA) module for WebSAT so as to achieve a well integrated and user-friendly system.

Methodology: The research team used interviews, focus groups, observation sessions and surveys as their means of collecting data on the aviation maintenance processes at FedEx. Methodologies such as contextual design, task analysis, the development and use of personas and scenarios, usability inspection methods and usability testing were integrated into a structured design process achieving a methodology that is both user-centered and compatible with current best practice in product design and development. The following stages were adopted for the development of the TA module of the WebSAT prototype: (1) Identification of user needs and translation into metrics for the product (2) Generation of three interface design concepts (3) Iterative testing with low fidelity prototypes for concept selection.

Results: Technical Audits module for WebSAT. A snapshot of the module is shown below.

Recent Accomplishments: In addition to the development of the TA module, the research team has demonstrated its functionality to the FedEx group using various auditor scenarios. The team conducted a user profile survey to establish various user categories and generate personas for the WebSAT development so as to enhance the user experience with the interfaces.



Primary Investigator: Anand K. Gramopadhye, Clemson University, Clemson, S.C.

The Operator's Manual for Human Factors in Aviation Maintenance

FAA Sponsor Organization: Flight Standards Service, Aircraft Maintenance Division

Purpose and Rationale: Written in response to industry requests for "simplified instructions," the Manual is a short and concise listing of six key factors on human factors in any maintenance organization.

Methodology: A team of industry, government, and academic human factors practitioners combined wisdom and experience to briefly explain why each topic is critical, how to address the topic, how to measure success, and key sources for additional information. Chapters cover Event Investigation, Documentation, Training, Shift Turnover, and Fatigue/Alertness. The final chapter addresses the issue of program sustainment and cost justification.

Results: Launched Operator's Manual for Human Factors in Aviation Maintenance on September 25th, 2005. The manual can be found at http://www.hf.faa.gov/opsmanual.

Recent Accomplishments: Unveiled Operator's Manual at a two-day FAA Human Factors Conference hosted by JetBlue Airways. Approximately, sixty representatives from different airlines and MROs attended the conference.

Primary Investigator: William J. Johnson, Federal Aviation Administration, Chief Scientific and Technical Advisor for Aviation Maintenance Human Factors.

Evaluation of Broadband Applications to Aircraft Maintenance Safety

FAA Sponsor Organization:

Purpose and Rationale: The goal of this research is to determine the extent to which human-centered design contributes to the successful application of emerging technologies in aviation maintenance. This includes, but is not limited to: training-on-demand, video-on demand, wireless access to technical documentation and much more.

Methodology: A detailed model and computer simulation of the line maintenance process was developed after shadowing line maintenance crews at a major air carrier facility over a period of three months. This model describes: (1) the physical layout of the facility including arrangement of artifacts and the distances between them; (2) the artifacts used by technicians along with a quantification of the time and effort required to use them; (3) the cultural relationships between all participants in the maintenance process; (4) the flow of information between participants; and (5) the sequence of steps required to service an inbound aircraft including: routine inspections, scheduled maintenance, deferred items, squawks reported by the flight crew, and squawks discovered during inspections.

Results: Models were used to evaluate present applications of computer/broadband technology and to make specific recommendations about how computer and broadband could be successfully deployed in the future. The flow model suggested the need for technology that improved the way technicians share knowledge with each other, not only while working together on-shift, but also across shifts or even careers. The cultural model suggested the need to improve the passing of information about maintenance problems from flight crew to maintenance technicians. This could be accomplished by enhancing the means by which flight crews record maintenance squawks. The artifact model suggested the need to redesign the interface to electronic documentation systems so that the most frequently performed information-seeking tasks are the easiest and quickest to perform. The artifact model also points out that the acceptance of any particular application might depend on interface design issues such as ease-of-access and reliability. The ability of technicians to access and print documentation while out on the ramp would be beneficial. The sequence model showed how technicians spend a lot of time traveling about the facility and accessing information from electronic documentation systems. This echoes the need for remote access to electronic documentation systems.

Recent Accomplishment: A final report was completed including recommendations.

Primary Investigator: Stephen M. Casner, NASA Ames Research Center

Flight Technologies and Procedures Research

Flight technologies and procedures research addresses human factors considerations in the design, certification, and approval of new technologies, procedures, and capabilities that cut across several operational environments of major and regional airlines. Program Manager Dr. Tom McCloy directs research that includes:

- Development of a job aid for use by designers and certification personnel to identify and address human factors issues with flight deck technologies and systems during the certification process
- Human factors research to provide certification, operational approval, and training guidance, including input to Advisory Circulars, associated with implementation and integration of electronic flight bags on the flight deck. Also included is development of recommendations to mitigate risks associated with use of electronic flight bags.
- Human factors research to support development of minimum certification requirements and guidelines for the approval of new moving map displays depicting surface situation awareness, vertical profile navigation information, and required navigation performance. This includes research to evaluate and identify human factors issues with symbology being proposed for use on these displays to support the International Civil Aviation Organization symbology committee intending to standardize these symbols.

FAA Aircraft Certification Job Aid for Flight Deck Human Factors

FAA Sponsor Organization:

Purpose and Rationale: The purpose of this project is to continue development of the Certification Job Aid, which is a software-based decision-support tool. Additionally, the project supports deployment, installation, evaluation, and training of tool usage within the FAA. The Job Aid has been in the field a used by FAA certification team members for several years, and the content and functionality are updated with each annual delivery.

Methodology: In 2005, content of the Job Aid was updated by adding the following:

- Summaries of the information contained in Part 25 regulations related to design of flight deck equipment, tasks and procedures, and testing assumptions
- Part 25 advisory circulars, industry standards, and TSOs related to the design review of flight deck displays, controls, and systems
- Part 23 regulations and advisory circulars related to the design of flight deck displays, controls, and systems.

Results: Version 6.0 of the Job Aid that includes this new content was delivered to the FAA on September 30th, 2005.

Recent Accomplishment: Support was provided to begin training for approximately 600 individuals within the AIR organization. When this training is complete, all interested parties will have access to the Job Aid.

Primary Investigator: Beth Lyall, Research Integrations, Inc., Tempe, AZ

Use of Traffic Displays for General Aviation Approach Spacing:
A Human Factors Study

FAA Sponsor Organization: Flight Standards: Flight Technology Requirements AFS-430

Purpose and Rationale: A flight experiment was conducted by Volpe researchers to assess human factors issues associated with traffic display use for general aviation aircraft. The focus of the experiment was on self-spacing on IFR approaches and continued self-spacing during temporary loss of visual contact on VFR approaches. The traffic display technology under study led to proposals to modify flight rules.

Methodology: Sixteen pilots each flew eight VFR and IFR single-pilot approaches (with a safety pilot). They wore an eye-movement recorder. Eight pilots used traffic displays that only showed the traffic to follow, and eight pilots used traffic displays that also showed other nearby traffic. The VFR approaches included one with a Basic Traffic Display, one with display enhanced closing rate information (Range Monitor), and two with no traffic display. All but one no display approach included a one-minute loss of visual contact. The IFR approaches included Basic Traffic Display, Range Monitor, Range Monitor flown with autopilot coupled, and baseline (no spacing) conditions. The lead aircraft decelerated markedly on each approach except the baseline IFR approach. Spacing performance and flight technical error data were continuously recorded. Time to visually re-acquire the lead aircraft following loss of visual contact was obtained from audio/videotape. Eye movement recordings provided percentage allocation, dwell time, and time between fixations on the forward window, the traffic display, instrument panel, and other areas. Following each approach, pilots provided ratings on the six NASA-TLX workload dimensions. Questionnaires addressed pilot performance of the traffic display applications, situational awareness, and traffic display usability.

Results/Recent Accomplishment: All three IFR spacing conditions yielded spacing within 0.10 nm from that which was assigned. Glide slope deviations were lower in the Range Monitor and no-spacing conditions than in the Basic Traffic Display conditions. Re-acquisition of the lead aircraft was faster with the Range Monitor than with no traffic display, but only when traffic in addition to the lead aircraft was displayed on the Range Monitor. The pilots performed the spacing and traffic awareness applications without excessive workload, although each of the two applications added to pilot workload. Eye movement recording suggested that traffic display use reduced the ability to detect non-displayed traffic by one-third. These results provide empirical evidence to guide the formulation of standards for the performance of traffic display applications under revised flight rules.

Primary Investigators: Eric Nadler, Alan Yost, Volpe NTSC, Cambridge, MA

Flight Symbology

FAA Sponsor Organization: Aircraft Certification Service

Purpose and Rationale: The objective of this project is to determine what aeronautical chart symbology is appropriate for electronic presentation on moving map and electronic chart displays. The issue is complex because display technology varies widely, from inexpensive small hand-held displays for general aviation, to high-end avionics for transport operations. Some manufacturers have developed their own symbols, resulting in a variety that could be confusing and potentially misleading. The goals of this effort are to identify features of navigation symbology that are problematic when presented on electronic displays and develop a method to design and evaluate symbology that takes into account the different media (e.g., paper vs. electronic) and platforms on which they will be displayed. Results of the research are expected to be of use to industry and the aviation authorities that are setting symbology standards.

Methodology: Volpe researchers designed and implemented two different symbology experiments, with the goal of supporting efforts for developing symbol standards. The purpose of the first experiment was to determine if there are key features that are necessary for symbols to be recognized, i.e., symbol stereotypes. The table below shows some of the current variations of the Distance-Measuring Equipment (DME) symbol as an example. The purpose of the second experiment was to test the intuitiveness of navigation symbols that are constructed from feature rules (e.g., an outer circle implies that it is a "fly-over" point). Pilots were recruited from airlines, the Air Line Pilots Association, military, and local aero clubs to participate in the experiments.

	United States Symbol	International Civil Aviation Organization (ICAO) Symbol	Industry Recommendation (SAE ARP 5289)
DME Symbol			

Table. Variations in the DME symbol tested in the first experiment

Results/Recent Accomplishments: A technical report discussing results of the two studies was published in September 2005. Stereotypical shapes for navigation symbols were identified despite the size, color, and fill with which the test symbol shapes were presented. Additionally, the usability and intuitiveness of symbol-feature rules for modifying navigation symbols were validated. Pilots were generally able to learn and apply these rules, although they were better able to apply the rules when more information was provided. The results of the studies contribute to development of recommendations to FAA and industry regarding electronic symbology for navigation information. The results of the studies are planned to be used by the Society of Automotive Engineers (SAE) G-10, Aerospace Behavioral Engineering Technology Committee, Electronic Charting Subcommittee in updating the recommended symbol set in Aerospace Recommended Practice (ARP) 5289. In addition:

- A paper discussing research issues in the design of symbols for navigation displays was presented at the 23rd Digital Avionics Systems Conference (DASC) in October 2004.
- Researchers presented ongoing activities for the Flight Symbology research program at the January, May, and August meetings of the SAE G-10 Committee for Aerospace Behavioral Engineering Technology, Aeronautical Charting subcommittee. This group plans to use the results of Volpe's flight symbology studies as input in updating the recommended symbol set in SAE ARP 5289.

Primary Investigators: Divya Chandra, Michelle Yeh, Volpe NTSC, Cambridge, MA

Electronic Flight Bag

FAA Sponsor Organization: Aircraft Certification Service and Office of Flight Standards

Purpose and Rationale: The main goal of this work is to identify, understand, and help the FAA address human factors issues related to Electronic Flight Bag (EFB) technology. Although EFBs may look like familiar equipment, they are new devices from a flight deck perspective because of their flexible configurations and functionality. The FAA put forth a streamlined field approval process for EFBs in Advisory Circular (AC) 120-76A, "Guidelines for the Certification, Airworthiness, and Operational Approval of EFB Computing Devices" (March 2003). This AC addresses human factors considerations, but the procedure for doing an evaluation is not specified. The focus of the current effort is to develop more practical aids for field evaluations of EFBs by non-human factors experts. We expect that the tools will benefit the FAA, system designers, and operators by providing structure for human-factors evaluations. The tools will be customized for both Aircraft Certification specialists and Flight Standards inspectors.

Methodology: The bulk of effort was spent on developing preliminary paper-based tools to assist Flight Standards inspectors in evaluating EFBs. To develop these new tools, Volpe organized and led a drafting team with participants from FAA Flight Standards and Aircraft Certification. Within Flight Standards, the team included representatives from FAA Headquarters, the New England All Weather Operations group, and the Seattle Aircraft Evaluation Group. The team produced a draft EFB Job Aid that contains a "Notice" and seven appendices. The draft was released for industry comment in late August, 2005. Volpe led the effort to develop three appendices focused on human factors issues. Other portions of the draft, which focus on the approval process, were primarily authored by FAA staff, with Volpe input where appropriate. The purpose of the Job Aid is to provide additional guidance to the FAA and industry regarding the approval process for installation and operational evaluations of EFB systems.

A low-level of effort was spent on honing the tools previously developed for Aircraft Certification. These tools are now mature. Discussions with FAA flight test pilots and engineers confirmed the value of the tools.

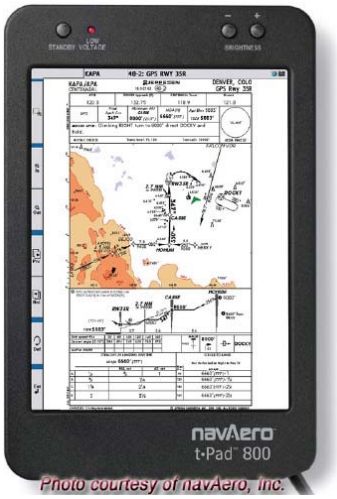


Photo courtesy of navAero, Inc.

Results/Recent Accomplishments: Volpe researchers developed a draft EFB Job Aid for use by Flight Standards inspectors. This document contains three new tools for assessing EFB human factors issues. The first tool (Appendix 4) is a comprehensive desktop evaluation guide. The second tool (Appendix 5) is a guide for developing scenarios for simulator and flight test evaluations with EFBs. The last tool (Appendix 6) helps inspectors record observations from line flights or flight/simulator tests. In September, 2005, Volpe hosted an FAA-Industry EFB meeting at which the draft EFB Job Aid was presented and discussed with over 100 representatives from airlines and other aircraft operators, original equipment manufacturers, and international authorities. In addition, Volpe:

- Discussed EFB usability assessment tools for Aircraft Certification with flight test pilots and engineers at the FAA Aircraft Certification Avionics Workshop in July 2005.
- Published a 2005 EFB industry review in April, 2005. The review provides information about EFB systems, software/content, and hardware that are currently on the market or in active development.

Primary Investigator: Divya Chandra, Volpe NTSC, Cambridge, MA

Guidelines for Certification of Head-Up Displays

FAA Sponsor Organization: Aircraft Certification: Transport Airplane Directorate ANM-100

Purpose and Rationale: Manufacturers are meeting an increased demand for head-up displays (HUDs) by marketing new models with various innovative features. These HUDs present human factors issues with regard to accessibility to the information displayed, where the HUD elements should be sufficiently conspicuous so that critical information is apparent. However, the display should not interfere with the out the window (OTW) view or with other nearby information. These two goals tend to be contradictory: a large, detailed, information-rich, and centrally located indicator design will also tend to clutter the OTW view and the display itself. However, a small, basic, information-impoverished and peripherally located indicator design may be difficult to use for its intended task. From a human factors perspective, the HUD design must achieve a balance between these goals. FAA certifiers need guidelines for evaluating the success of this balance as presented in a HUD design that is presented for certification.

Methodology: An experiment evaluated the impact of design detail on altitude and airspeed indicators, where such details include frames, full gradation labels, and large-area pointers. For each experimental trial, air transport pilots flew an approach which included simulated traffic events. The primary independent variable was the level and design of detail for tape-style indicators of airspeed and altitude. There were three conditions: Full, Minimal, Alternative. The Full format approximated the degree of detail (and clutter) found on contemporary civil HUDs, while the Minimal format approximated the detail found on some military HUDs. The Alternative format was also a low-detail HUD, but one that attempted to maximize the distinctiveness of indicator elements. Three approaches were flown for each format condition by each pilot. Dependent variables were flight technical error, eye-tracking fixation duration and frequency on each indicator, traffic detection time, and subjective ratings of the formats.

Results: Preliminary results indicate that pilots strongly preferred the Full formats. The Full format does not appear to be systematically associated with slower traffic detection times, even for traffic that appears within the manipulated indicators (where presumably the greater pixel use of the Full format would result in more frequent masking of traffic). Indeed, for traffic that does not appear in the manipulated indicators, there is a trend for reaction time to be fastest for the Full format, suggesting the possibility that such full details facilitate the perception of indicator values, leaving more time for traffic scanning.

Recent Accomplishment: Researchers initiated a tape detail study, are nearing completion of data collection, and have started some preliminary analyses.

Primary Investigator: Michael Zuschlag, Volpe NTSC, Cambridge, MA

General Aviation Research

Program Manager Dr. William Krebs directs general aviation (GA) research that focuses on reducing fatalities, accidents and incidents within the GA flight environment. One of the Administrator's Flight Plan Safety Objectives focuses directly on GA – reducing the number of fatal accidents. The GA environment is defined as all flights that are conducted under FAA Part 91, as well as the GA maintenance community. Human factors research addresses better methods for detection, classification, and reporting of accidents involving human factors, developing certification and flight standards and guidelines based on human factors research, and identifying and implementing intervention strategies to reduce accidents or mitigate the impact of GA accidents.

Research objectives are focused on reduction of weather-related and maneuvering flight accidents, controlled-flight-into-terrain, and pilot field-of-vision capabilities and limitations. Other objectives include loss of primary flight instruments during instrument meteorological conditions, the implications of future technology on human performance, and improving GA training.

Human Error and Commercial Aviation Accidents:
A Comprehensive, Fine-Grained Analysis using HFACS

FAA Sponsor Organization: Flight Standards Service, General Aviation & Commercial Division

Purpose and Rationale: The Human Factors Analysis and Classification System (HFACS) is a theoretically based tool for investigating and analyzing human error associated with accidents and incidents. Previous research has shown that HFACS can be reliably used to identify general trends in the human factors associated with military and general aviation accidents. The aim of this study was to extend previous examinations of aviation accidents to include specific aircrew, environmental, supervisory, and organizational factors associated with 14 CFR Part 121 (Air Carrier) and 14 CFR Part 135 (Commuter) accidents using HFACS.

Methodology: Commercial aviation accident data (14 CFR Part 121 – air carrier; 14 CFR Part 135 – commuter) from calendar years 1990-2002 were obtained from databases maintained by the National Transportation Safety Board (NTSB) and the FAA's National Aviation Safety Data Analysis Center (NASDAC). The data were culled to include only those accidents that involved aircrew or supervisory error. Of the remaining 1,020 accidents, 181 involved air carrier aircraft and 839 involved commuter aircraft. Six pilots served as subject matter experts (SMEs) and read the narrative and tabular data obtained from both the NTSB and the NASDAC to classify each aircrew or supervisory causal factor within the HFACS framework.

Results: The majority of causal factors were attributed to the aircrew and the environment, with decidedly fewer associated with supervisory and organizational causes. When organizational influences were observed, they typically involved operational processes such as inadequate or non-existent procedures, directives, standards, and/or requirements, or in the case of commuter operations, inadequate surveillance of operations. Air carrier accidents were typically associated with the manner in which procedures or directives were communicated, assuming they existed at all. In contrast, commuter accidents were more often associated with a lack of organizational oversight. Crew resource management (CRM) failures were identified in nearly one out of every five air carrier accidents examined. Even more interesting, the nature of the CRM failure differed between the two commercial operations. That is, while over 60% of the CRM failures associated with air carrier accidents involved "in-flight" CRM failures (e.g., in-flight crew coordination, communication, monitoring of activities, etc.), over 80% of the CRM failures observed during commuter operations involved "preflight" activities (such as planning and briefing).

Similar to other civil aviation accident data, there was little variation in the distribution of unsafe acts committed annually by aircrew flying either air carrier or commuter operations. When accidents occurred in either type of commercial operation, they were typically associated with more skill-based errors followed by decision errors, violations, and perceptual errors respectively.

Recent Accomplishments: An OAM Technical Report titled Human Error and Commercial Aviation Accidents: A Comprehensive, Fine-Grained Analysis using HFACS is under review.

Primary Investigators: Carla A Hackworth, Civil Aerospace Medical Institute, Oklahoma City, OK; Scott Shappell, Clemson University, Clemson, SC

A Human Error Analysis of General Aviation Accidents Occurring in Alaska Versus the Rest of the United States Using HFACS

FAA Sponsor Organization: Flight Standards Service, General Aviation & Commercial Division

Purpose and Rationale: This research examined human error associated with general aviation (GA) accidents that occurred in Alaska versus those that occurred in the rest of the United States (US) to see if the patterns of human error differ. The scope of this research includes human error analyses obtained using the Human Factors Analysis and Classification System (HFACS) as well as demographic analyses. In the end, accident data and the subsequent human error patterns will form the basis for proposed interventions.

Methodology: GA accident data from calendar years 1990-2002 were obtained from databases maintained by the National Transportation Safety Board and the FAA's National Aviation Safety Data Analysis Center (NASDAC). In total, 24,978 GA accidents were extracted for analysis. Only 14 CFR Part 91 accidents were included in the analyses. This analysis was primarily concerned with powered aircraft and thus the data were reduced to include only accidents involving powered fixed-wing aircraft, helicopters, and gyrocopters. The remaining 22,248 accidents were then examined for aircrew-related causal factors. A total of 17,808 accidents were included in the database and submitted for further analyses using the HFACS framework.

Results: An overall review of the GA accident data yielded the following results: the most prevalent error noted in the accident data over the past decade was skill-based errors associated with 73% of the accidents, followed by decision errors (28%), violations (13%), and perceptual errors (7%). Analysis of unsafe acts revealed that there were slightly more decision errors, and fewer skill-based errors, perceptual errors and violations occurring in Alaska. A fine-grained analysis of each of the unsafe acts revealed unique differences between the specific types of errors occurring in Alaska versus the rest of the US. Skill-based errors revealed that accidents in Alaska were more likely to be associated with a loss of directional control of the aircraft, in addition to an inadequate compensation for wind conditions. Accidents in Alaska were far more likely to be associated with the decision to utilize unimproved landing, takeoff, taxi areas or unsuitable terrain. Visual Flight Rules into Instrument Meteorological Conditions (IMC) continued to be the top violation for accidents in both Alaska and the rest of the US, with a higher percentage occurring in Alaska. Demographic analyses revealed that the majority of accidents in Alaska occurred during clear conditions (daytime and Visual Meteorological Conditions), and were primarily non-fatal.

Recent Accomplishments: A comprehensive report on the complete analyses of this project was submitted for publication as an Office of Aerospace Medicine technical report in August 2005. The data were presented at the Aviation North Expo in Fairbanks, AK in October 2004 and at the International Symposium of Aviation Psychology, Oklahoma City, OK in April 2005.

Primary Investigator: Carla Hackworth, Civil Aerospace Medical Institute, Oklahoma City, OK

Transfer of Training Effectiveness of a Flight Training Device (FTD)

FAA Sponsor Organization: Flight Standards Service, General Aviation & Commercial Division

Purpose and Rationale: to determine how the specific FTD fared, in terms of actual incremental transfer effectiveness, relative to PC-based aviation training devices (PCATDs), and in comparison with the advisory circular criterion allowing 10 hours of instrument training to be completed in an approved PCATD. Transfer data for the Frasca device had not been available previously, and this effort was an attempt to establish a baseline for this approved device for comparison with other training devices. Another goal was to determine at what point, in number of hours, training in the FTD or the PCATD was no longer as effective as training in the airplane.

Methodology: An experimental instrument flight-training course was developed using the Frasca 141 FTD and Piper Archer III aircraft (university courses AVI 130, Basic Instruments, and AVI 140, Advanced Instruments). To determine incremental transfer (how much a particular block of training hours transfers depending upon its serial position in the training curriculum), four experimental groups received 5, 10, 15 and 20 hours of Frasca 141 training during the instrument curriculum. In this design, the FTD 5 and FTD 10 groups provided a systematic replication for the PCATD 5 and PCATD 10 groups in an earlier study so that current results could be compared directly with those obtained previously. PCATD training (one group; five hours of training) was conducted in the ELITE approved PCATD, version 6.0.2. A control group received all training in the airplane. Dependent measures were trials in the airplane to proficiency, time to complete the flight lessons in the airplane, and total course completion time in the airplane for each course.

Results: A total of 124 participants successfully completed the AVI 130 course and took the check ride, 75 of whom passed on the first attempt and 49 who passed on the second attempt. Dual-instruction time in the airplane to complete the course to criterion levels was 22.35 hours for the airplane group, whereas the PCATD and FTD groups required 18.31 and 20.87 hours respectively. For the advanced course, the figures were 26.38 for the airplane and from 20.79 to 25.78 for the experimental groups using training devices. A smaller number of trials were required to reach criterion in the airplane for the FTD groups for 10 of the 12 flying tasks. A number of significant differences were found between the airplane-only group and the trainer-instruction groups for various lessons within the course, generally favoring the groups using training devices. A savings of approximately 50% was found when using the FTD to train cross-country instrument flight (15- and 20-hour FTD groups). Examination of the Incremental Transfer Effectiveness Ratios indicate minimal savings in training time for the FTD 10-hour group over the FTD 5-hour group, nor was there any gain for PCATD time beyond 10 hours (analyzed with previous data from PCATDs).

Recent Accomplishments: It was concluded that more training in the FTD or the PCATD is not necessarily better in terms of time savings. Although one may gain a fractional hour reduction in time required in the airplane for an hour or more of additional training-device time, the returns generally follow the established negatively accelerated function such that earlier hours in the training-device curriculum provide greater savings in the airplane. In summary, no appreciable benefit was found for more than five hours of training on instrument tasks in either the FTD or the PCATD.

Primary Investigators: Henry L. Taylor, Donald Talleur, Tom Emanuel & Esa Rantanen, Institute of Aviation, University of Illinois at Urbana-Champaign, Champaign, IL

General Aviation Private Pilot Survey/Designated Pilot Examiner Program Assessment

FAA Sponsor Organization: Flight Standards Service, General Aviation & Commercial Division

Purpose and Rationale: In order to meet objectives set forth in the Administrator's Flight Plan, the General Aviation and Commercial Division plans to improve the Designated Pilot Examiner (DPE) program. A DPE administers a practical test to evaluate the pilot's knowledge of and skill to perform a task. Problems arise when application of the DPE test criteria varies between examinations, examiners, or pilots. Two surveys will be conducted to determine the effectiveness of the examiner oversight program. One survey will be administered to all newly certified general aviation single-engine-land rated private pilots. In order to provide a balanced perspective of the practical test standard process of single-engine-land certification, it is proposed that DPEs be given the opportunity to comment on the process as well. A second survey will be administered to all DPEs across the United States.

Methodology: Newly certified general aviation (GA) pilots will receive an anonymous and voluntary survey to complete and return by mail. In an attempt to maximize response rates, the survey will have an attached cover letter explaining the purpose of the survey and asking for feedback regarding flight training and testing experiences. Respondents will be assured that the survey is completely anonymous and voluntary and that if any of the questions make them feel uncomfortable, they should skip them. Returned surveys will be scanned into a database through the use of Teleform software. Summary reports for the surveys will be created for each region that has at least eight respondents. In addition, an overall report will be created.

Results/Recent Accomplishments: OMB materials including the Federal Registry announcement were developed and submitted. Institutional Review Board materials were developed, submitted, and approved. AFS-800 has asked the registry to assist with the survey project. The registry is to gather the pertinent names and addresses for the GA pilots and subsequently mail the survey to respondents. However, there a few criteria that they cannot match with the original target population (e.g., region of respondent identified, first-time applicant with no failures in the past); therefore, the project is on hold waiting for direction from AFS-800.

Primary Investigator Carla A Hackworth, Civil Aerospace Medical Institute, Oklahoma City, OK

How General Aviation Pilots Use Weather Information

FAA Sponsor Organization: Flight Standards Service, General Aviation & Commercial Division

Purpose and Rationale: The U.S. general aviation (GA) fatality rate remains unacceptably high, making it a high priority in the Administrator's Flight Plan. The leading cause of GA fatalities is bad weather. A powerful way to counter bad weather is to make top-quality weather information available to pilots. But do pilots actually use this information fully and effectively? Answering this question was the main goal of this research.

Methodology: Over 200 GA pilots were surveyed in seven locations across five widely separated states. Both structured and unstructured questions were asked pertaining to: (1) which weather providers and products pilots preferred; and, (2) how often and how much time did they typically spend using them during bad-weather flight planning, both before and after takeoff. In a second phase of the investigation, 24 hours of voice recordings containing 306 calls from three Aviation Flight Service Stations (AFSS) were analyzed to determine what types of briefings pilots requested, who requested them, and what information AFSS specialists provided.

Results: The group-wide estimated average time spent on preflight weather briefings for a "standard flight" of four hours into challenging weather was 19.8 minutes. While this amount of time appeared adequate, two issues emerged: (1) some pilots reported spending as little as 3-4 minutes on preflight briefings and/or as little as 0-1 minutes on en-route updates; (2) while highly sophisticated weather products are now readily available to pilots at Fixed Base Operations and over the Internet, most pilots still seemed to prefer relatively simple sources such as METARs, TAFs, ATIS, AWOS, and The Weather Channel. Thus, it is likely that a significant number of pilots are still not spending enough time on weather briefings before flight, on updates while in-flight, and are not using the highest-quality information currently available to them. Data from the second phase, briefing requests of AFSS, indicated that for VFR flights, the standard briefing was most often requested (43%), followed by the abbreviated briefing (38%). Pilots declined a briefing in 15% of the contacts. Further analyses indicated a list of specific items that were provided in 85% of the briefings. In about 10% of the cases, pilots actually changed their flight plans as a result of the briefings.

Recent Accomplishments: Civil Aerospace Medical Institute personnel visited six sites and obtained data from a seventh, with a total of over 220 pilots responding. Preliminary analyses were completed and reported to the sponsor for inclusion in a larger deliverable to instruct GA pilots on proper use of weather information. Data were extracted from 24 hours of voice recordings of contacts with AFSSs. Additional examinations of the data are under way to explore further details of pilot use of weather information and sources.

Primary Investigator: William R. Knecht, O. Veronika Prinzo, FAA Civil Aerospace Medical Institute, Oklahoma City, OK

Unmanned Aircraft Operator Medical, Qualification, and Training Requirements

FAA Sponsor Organization: Flight Standards Service, General Aviation & Commercial Division

Purpose and Rationale: to support the rapidly growing industry of unmanned aircraft (UA) as it transitions from military to non-military applications. Historically, flight operations assumed an onboard pilot controlling an aircraft to ensure safe operation in the national airspace system. An unmanned aircraft may be controlled by a pilot or operator from a distant ground station. In some cases, the UA's flight path is based on pre-programmed global positioning system waypoints, and the operator may be working autonomously with very limited control over aircraft maneuvering. UA offer exciting opportunities for civil aviation; however, before non-military UA operations are fully integrated into the NAS, the FAA needs to define operator medical, qualification, and training requirements.

Methodology: The technical approach included a literature review of existing research on UA pilot requirements, an analysis of current and potential UA commercial applications, an analysis of current and potential UA airspace usage, and an analysis of current and potential control hierarchies. Researchers also reviewed several proposed categorization schemes for UA systems. The results of the reviews and analyses were used during the assembly of a team of subject matter experts who reviewed current Class 1-3 medical requirements as well as suggestions for other certification schemes. They made recommendations regarding how those requirements should be relaxed or strengthened for each of a proposed set of pilot categories. In addition, the team discussed pilot prerequisites (e.g., private pilot certificate) necessary for successful UA flight training. Separate meetings with groups from NASA and The Society of Automotive Engineers (SAE) - G10 were used to establish a preliminary task analysis for UA pilots that could be used to make recommendations for UA pilot training and testing requirements.

Results: The research provided a basis for establishing an initial recommendation for use of the Class 3 medical certificate for unmanned aircraft pilots. Justification for the certification level was based on the perceived risk of pilot incapacitation and subsequent consequences of such incapacitation. Future applications might require establishing higher certification levels. An analysis of manned aircraft experience as a prerequisite for unmanned aircraft pilots was inconclusive. Future research should address this question. A task analysis of the UA pilot task suggested similarities with taskings for a manned aircraft. However, at least three areas were identified as unique to UA. These areas were: data link issues; detect, sense, and avoid procedures; and control handoff issues. These areas are critical for establishing effective training and testing standards for unmanned aircraft pilots.

Recent Accomplishments: Findings were briefed to the SAE-G10 committee and have been presented to FAA sponsors. The G10 committee is incorporating the findings into its research document. A paper reporting the results has been completed and is being submitted as an OAM technical report.

Primary Investigator: Kevin W. Williams, Civil Aerospace Medical Institute, Oklahoma City, OK

Flight Display Symbology Evaluation Tool

FAA Sponsor Organization: Aircraft Certification Service, Avionics System Branch

Purpose and Rationale: Recent technological advances have altered the information available for display in the cockpit. Since standard symbols would reduce errors, new symbol sets are being constructed and proposed. This project is constructing an evaluation tool that will compute the discriminability among proposed sets of symbols. The tool will only ensure visual discriminability, and will not take into account more cognitive processes affecting categorization error. It is believed that if symbols are not visually discriminable, errors are likely to occur.

Methodology: Results of last year's study by Michael Zuschlag (Volpe NTSC) on the assessment of proposed traffic symbol set were examined and were fit by an image discrimination model. It appeared that some of the poor predictions were the result of the fact that any difference at all in

the images generates an image difference, while the observer appeared to categorize somewhat independently of size and presumably of position.

Results: A version of a NASA image discrimination model was developed that includes both size compensation and position compensation. Researchers applied this model to seven of the symbol pairs that led to the most errors in the Volpe experiment. The predictions of experimental results by the model were improved. The model takes as input the luminance values for the pixels of two symbol images, the effective viewing distance, and provieds as output the discriminability in just-noticeable-differences (d'), the size reduction of the larger symbol, and the x and y offset in pixels needed to minimize the discriminability.

Recent Accomplishment: A preliminary tool for assessing the discriminability between a pair of symbols has been completed.

Primary Investigator: Albert Ahumada, NASA Ames Research Center, Moffett Field, CA.

Enhanced General Aviation Decision-Making through On-Line Training and a CFI Resource Library

FAA Sponsor Organization: Flight Standards Service, General Aviation & Commercial Division

Purpose and Rationale: Forty percent of fatal general aviation accidents are weather-related. Current decision training is primarily based on outdated theory and anecdotal evidence. In this project, researchers are examining recent studies into how people learn, remember, make decisions, and build expertise. They will then utilize this information to develop an interactive and validated set of educational materials to enhance pilot judgment and decision- making. An additional goal is to provide Certified Flight Instructors the tools necessary to teach effective and adaptive decision making in today's pilots.

Methodologies: A cognitive literature review was completed. A critique of current pilot training strategies (ground and flight training) and tools (CD ROM, Web-based) was conducted. Analysis of ASRS general aviation reports over the past ten years dealing with weather related incidents was completed. As well as NTSB weather related accidents were investigated.

Results: In the first year of the project, work was focused on development of the pilot training tool. This involved (a) comprehensive collection of state-of-the-art cognitive strategies to enhance decision making, expertise building, learning, and memory, (b) identification of what is commercially available so that a free web-based tool will address training gaps, (c) identification of factors contributing to poor weather assessment including: overestimation of flying abilities, lack of understanding of implications of flying into low visibility conditions, distractions and interruptions, and poor instrument scans, and (d) identification of the first training focus – thunderstorms.

Recent Accomplishments: A research paper was produced: *Enhanced General Aviation Decision Making: Weather Assessment during Preflight Planning*. This information was incorporated into the General Aviation & Commercial Division Pre-Flight Weather Guide Handbook.

Primary Investigator: Bettina L. Beard, NASA Ames Research Center, Moffett Field, California.

A New Approach to Aviation Accident/Incident Prevention/Mitigation

FAA Sponsor Organization: Flight Standards Service, General Aviation & Commercial Division

Purpose and Rationale: If improvements in safety are to be realized, a more systematic methodology is needed for generating intervention/prevention strategies that can tie into human error frameworks like HFACS. Such a methodology will help ensure that factors affecting human performance are addressed at multiple levels and from multiple directions, thereby facilitating the development of effective intervention strategies rather than a single, narrowly focused design fix.

Methodology: This study is divided into two efforts (1) independent validation of four intervention methodologies using safety recommendations from the NTSB, and (2) examination of proposed FAA aviation safety programs using a prototype intervention matrix that maps the unsafe acts of operators (i.e., skill-based errors, decision errors, perceptual errors, and violations) onto several intervention approaches.

Results: Analysis of NTSB recommendations from 1998 to 2003 indicates that current safety recommendations tend to focus more on improving the design of systems or organizational change rather than focusing on individuals in the field. While these recommendations are well-intentioned and often specific to a particular accident, they may be misplaced or too narrow in scope. This may help explain why the percentage of accidents associated with human error has not changed appreciably over the last 15 years. To ensure that safety professionals generate effective intervention strategies, rather than a single "knee jerk" fix to a problem, knowledge of all viable interventions is required. At least four broad categories of interventions appear tenable within the aviation industry. These are Administrative/Organizational, Mechanical/Engineering, Human/Crew, and Task/Procedure. Based on these findings a prototype matrix was developed, called the Human Factors Intervention Matrix (HFIX) that pits the unsafe acts individuals commit against five different intervention approaches. Next, the efficacy of the HFIX prototype was examined against the JSAT/JSIT data. The results suggest that even though the JSAT/JSIT safety programs were more multi-dimensional than other government safety programs (e.g., NASA), they still did not appear to fully address the current accident trends in commercial and general aviation. At least on the surface, it appears that there are gaps in the safety program that should be addressed. For example, there was an apparent bias toward interventions aimed at pilot decision-making, particularly those utilizing organizational and human approaches. While this is not inherently bad, previous HFACS analyses suggest that additional effort should be placed on skill-based errors and violations, two areas that appear underrepresented given current trends in the accident data.

Recent Accomplishments: Completed Flight Plan Target that called for development and validation of the Human Factors Intervention Matrix (HFIX) for use by AVR.

Primary Investigators: Carla A Hackworth, Civil Aerospace Medical Institute, Oklahoma City, OK; Scott Shappell, Clemson University, Clemson, SC

Modify, Test, and Validate Vision Model to Predict Target Recognition

FAA Sponsor Organization: Flight Standards Service, Flight Tech & Procedures Division

Purpose and Rationale: To characterize the ability of UAV viewing systems to support target detection and recognition. Existing system evaluation methods require expensive and time consuming subjective experiments. This project seeks to replace subjective testing with the Spatial Standard Observer (SSO), a simple model of human detection and discrimination. The first goals of the project are: (1) to test the SSO model on an existing set of subjective data, and (2) develop a web-based prototype application to predict detection and identification of relevant targets.

Methodology: The SSO model was tested on digital images provided to the researchers by the Night Vision and Electronic Sensors Directorate of the US Army, Ft. Belvoir, VA. The images (288) included various military vehicles, in both visible and infrared versions, digitally blurred by various amounts, as well as human identification performance data for the same images. The SSO is a simple model of visual foveal contrast detection. It has been extended recently to predict pattern discrimination and identification. The SSO model was further modified to predict identification performance through addition of a normalized template matching rule. The performance of this model is controlled by a single parameter: the standard deviation of the internal noise that is added to each image before matching.

Results: Model predictions were generated for target identification for both visible and infrared image sets, for six amounts of blur (5, 10, 15, 20, 25, and 30 pixels), and for many levels of internal noise. Model predictions were compared to human subjective data for both visible and infrared image sets. Noise levels were found (about –2.25 log units) that rendered model performance close to that of the human observers. Other observations were: (a) identification performance for the model exceeded that expected from a simple image identification model plus guessing; (b) cropping the targets to exclude the background enhanced performance of the model and improved the agreement with human data; and, (c) the model predicts about equal performance for visible and infrared imagery, while human observers did slightly worse on infrared. Overall, these results, while preliminary, are promising and indicate the feasibility of an SSO-based tool for predicting target recognition, and for quantifying the utility of UAV viewing systems.

Recent Accomplishments: A report on use of the SSO in target recognition and other applications has been accepted for presentation at the IEEE SMC 2005 meeting, in a special session on *Computational Models of Human Performance in Aerospace Systems*. A preliminary version of the Web-based application was implemented and deployed. This working prototype serves mainly to test the feasibility of the application environment, which uses a Web Mathematica interface and back-end code written in Mathematica. Future versions will incorporate realistic optical and atmospheric effects, and will be calibrated in both geometric and photometric aspects.

Primary Investigator: Andrew B. Watson, NASA Ames Research Center, Moffett Field, CA

Visibility in the Aviation Environment

FAA Sponsor Organization: Flight Standards Service, General Aviation & Commercial Division

Purpose and Rationale: Visibility issues are a factor in a large number of general aviation accidents each year. Reduced visibility from continued flight into instrument meteorological conditions (IMC) often results in controlled flight into terrain (CFIT), or collision with ground-based obstructions and other aircraft. Poor visibility also is a factor in runway incursions and ground-based accidents. Complex and high contrast backgrounds also contribute to many mid-air collisions by reducing the detectibility of other aircraft. Many of these accidents occur in clear skies. Pilots often do not immediately recognize situations that may lead to poor detection and otherwise unsafe visual conditions and therefore fail to take appropriate action. This project has two main goals: 1) trying to better understand visual limitations under conditions of low visibility and decreased detection, and 2) to teach pilots how to better detect other aircraft and to more easily recognize unsafe visual conditions.

Methodology: Visual detection experiments are being conducted using images with different characteristics to determine which characteristics correspond to poor detection. We are also conducting visual detection experiments to determine the influence of temporal strobe light patterns on detection. These data will form the basis for instructional materials designed to help pilots recognize visual conditions under which aircraft or terrain detection is difficult. The instructional materials will include training in the basic tasks of visual acquisition including judgments of distance, direction, orientation, and relative altitude based on size and angular position. Training will also include recognition of flat light conditions and reduced contrast from atmospheric effects. We have developed an interactive program on the basics of detection that will form the basis of a final educational product in the form of a CD and/or web-based program.

Results: Basis function sets derived from aviation images using the sparse coding algorithm differ from those derived from land-based images. A sparse coding model as currently formulated does not provide significant advantage over Ahumada et al.'s detection model. Temporal staggering of strobe lights do not significantly improve detection over simultaneous flashing under the conditions tested here.

Recent Accomplishments: This year we have made progress on programming the simulator to expand our computer based-experiments to more realistic scenarios. We have collected detection data and compared the sparse-coding model predictions with those from Ahumada's model of visual detection. We have completed a short study on the influence of temporal strobe light pattern on detection thresholds. The above results have been presented at important international and national vision meetings. We have developed an interactive program on the basics of detection that will form the basis of a final educational product in the form of a CD and/or web-based program. This program helps pilots learn apparent size, orientation, and visual characteristics of aircraft located throughout the aviation visual environment.

Primary Investigator: Michael A. Crognale, University of Nevada, Reno, Nevada

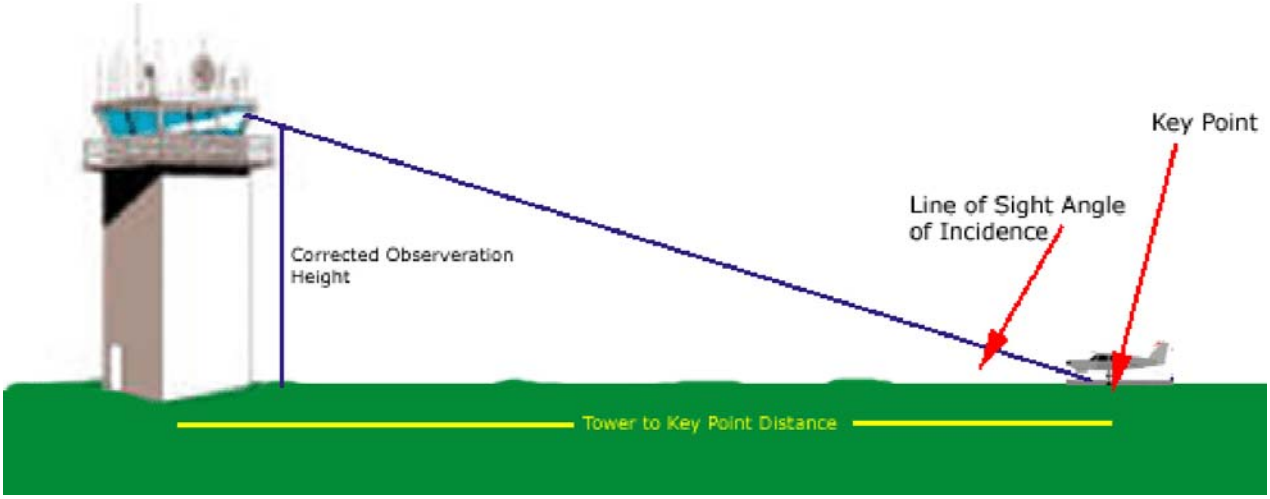
Air Traffic Control Tower Visibility Analysis Tool

FAA Sponsor Organization: Flight Standards Service, General Aviation & Commercial Division

Purpose and Rationale: The overall purpose of this research is to provide the FAA with a user-friendly software tool that provides quantitative information on the impact of Air Traffic Control Tower (ATCT) height on aircraft visibility. The objective for FY05 is to expand and enhance the ATCT visibility analysis tool (FAA Vis) that was developed for the FAA in FY04, to include additional capabilities. Specifically, these additional capabilities are to include: incorporation of the Air Force's Moderate Resolution Transmittance (MODTRAN) atmospheric transmission code into FAA Vis (to account for the effects of atmospheric attenuation on target observability), enhancement of the FAA Vis algorithms to reliably handle a wider range of observation luminance levels and to perform more accurate target-to-observer turbulence slant-path calculations, and to add new graphical user interface (GUI) elements to support the expanded capabilities.

Methodology: The technical approach that the U.S. Army Research Laboratory (ARL) utilized to accomplish the objective was to team with the U.S. Army's Night Vision and Electronics Sensor Directorate (NVESD) to update the working desktop version of FAA VisTool. NVESD personnel have experience with integrating MODTRAN into many of their sensor models and were able to handle this part of the project efficiently and reliably. The remaining enhancements were accomplished jointly between ARL and NVESD personnel.

Results/Recent Accomplishments: All elements of this project have been completed to date, except for implementation into the Web version of FAA Vis. (The 1st version of the visibility analysis tool is available on the Internet (www.hf.faa.gov/visibility) to all tower siting project teams and is now being used by them in planning for new control towers.) The present,



expanded version of FAA Vis now contains all of the features listed above, including a fairly broad set of standard atmospheric environments and supplemental conditions from which to choose from, within the MODTRAN-based atmospheric effects GUI section. (There is also an option for the user to define an arbitrary, but constant atmospheric attenuation parameter in lieu of the MODTRAN-calculated results.) The FAA Vis tool now has the *capability* to accurately predict the probability of detection, recognition, and identification of various aircraft by human observers as a function of range and ATCT height for most types of atmospheric conditions. Future work should include adequate empirical and/or experimental validation of this tool, particularly in the area of quantifying target (aircraft) discrimination difficulty criteria and critical

target (aircraft) dimensions. Ongoing work in this area has played a pivotal role in the creation of a new ATCT Siting Order, and has included the presentation and publication of a paper at and for the International Symposium on Aviation Psychology.
(see References @ www.hf.faa.gov/visibility).

Primary Investigator(s): Steven R. Murrill, ARL - Sensors and Electron Devices Directorate, Adelphi, MD, William “Kip” Krebs, ATOP-R&D, Washington, DC, and Glen Hewitt, ATOP-R&D, Washington, DC.

UAV See-and-Avoid Visibility Analysis Tool

FAA Sponsor Organization: Flight Standards Service - Flight Technologies and Procedures Division

Purpose and Rationale: The Federal Aviation Administration (FAA) is presently engaged in research to review the characteristics and performance of existing optical systems that could be used to enhance an unmanned aerial vehicle (UAV) operator's ability to see-and-avoid potential conflicts with other manned and unmanned aircraft. The purpose of this research is to provide the FAA with a user-friendly software tool that provides quantitative information on the available time that a UAV operator would have to respond to a potential conflict, given a particular imaging sensor/display system and a set of observation scenario parameters. The tool is to include drop-down windows for user input as well as text boxes and graphical charts for results output. The primary output of this tool will be the maximum available time that a UAV operator has to respond to a potential conflict, for the sensor/visibility scenario modeled. Other outputs will include probability-of- discrimination (detection, recognition, and identification) curves as a function of observation range.

Methodology: The technical approach that the U.S. Army Research Laboratory (ARL) will utilize to accomplish the objective is to team with the U.S. Army's Night Vision and Electronics Sensor Directorate (NVESD) to develop an interface between NVESD's Solid-State Camera (SSCAM) and Night Vision Thermal Imaging Systems (NVTherm) performance models, and the FAA's See-and-Avoid Detection and Recognition Visibility Analysis tool. The NVESD models will be used to generate all camera- and display-related performance parameters, while the FAA See-and Avoid tool will account for all atmospheric-, target-, and (human-observer) search-related performance effects. The FAA See-and-Avoid tool will combine all of the performance parameters to generate overall results, and will be developed by leveraging from the recently-enhanced Air Traffic Control Tower (ATCT) Visibility Analysis Tool (FAA Vis). The majority of the algorithms and routines used in the See-and-Avoid tool will be identical to those used in the most recent version of FAA Vis.

Results/Recent Accomplishments: The primary elements of this project have been completed to date, except for integration of all computational routines. The See-and-Avoid Detection and Recognition Visibility Analysis tool (built from the most recent version of FAA Vis) now has a file-based interface to import relevant camera- and display-related performance parameters from NVESD's SSCAM and NVTherm performance models, and a graphical user interface (GUI) to input human search and other observation parameters into the tool. Completion of the baseline version of this tool is expected within the next two months. At present, the tool uses a single value for the time required for a human to search for a target in the observation field-of-view (FOV). Future work should include incorporation of a more robust model/algorithm for search time that considers the effects of target-to-background contrast and background clutter characteristics. This See-and-Avoid visibility analysis tool will be a valuable asset to the FAA in its efforts to establish policy and rules for the safe operation of UAVs in general airspace. As part of this research project, ARL and NVESD researchers are also participating in a NASA-Ames led effort to assess the feasibility of using NASA's Spatial Standard Observer model to compute target detection and recognition discrimination criteria (N50's). Results from this effort will be reported on separately.

Primary Investigator(s): Steven R. Murrill, ARL - Sensors and Electron Devices Directorate, Adelphi, MD, and William "Kip" Krebs, ATOP-R&D, Washington, DC.

Aviation Safety Inspector (ASI) Training for Technically Advanced Aircraft

FAA Sponsor Organization: Flight Standards Service, General Aviation & Commercial Division

Purpose and Rationale: Recently, there has been an emergence of technically advanced "glass cockpit" aircraft within general aviation. Aside from technical challenges presented by the design of these advanced avionics systems, there are difficulties in acquiring a conceptual understanding of the functions offered by the avionics, developing system monitoring skills and habits, developing mode management and awareness skills, understanding when and when not to use automation, and maintaining manual flying skills. Operating aircraft with advanced avionics requires an additional set of knowledge elements and skills. Currently, FAA aviation safety inspectors (ASIs) are required to inspect technically advanced aircraft, check certified flight instructors, and conduct surveillance of designated pilot examiners who are certifying pilots operating technically advanced aircraft. However, many of the aviation safety inspectors within the FAA workforce completed flight training prior to the entry of advanced avionics. Therefore, the aim of this project is to provide aviation safety inspectors the skills needed regarding technically advanced aircraft (TAA). Specifically, General Aviation ASIs need to be more knowledgeable of the capabilities, limitations, and the normal and emergency operating procedures in these aircraft so that they may safely and competently perform their inspection, checking, and surveillance function for general aviation operators who have these types of aircraft.

Methodology: Two courses, the Qualification Course for Technically Advanced Aircraft and Evaluation Course for Technically Advanced Aircraft, have been developed to educate general aviation ASIs on the capabilities, limitations, and the normal and emergency-operating procedures in technically advanced aircraft. The initial course is to provide an overview of three major TAA electronic flight systems used in general aviation. The Evaluation course will instruct ASIs on how to evaluate pilots and DPEs who operate a TAA. The course will provide ASIs with the minimal proficiency standards required to operate a TAA. After completing each of these courses, ASIs will complete course evaluations on their impressions of the course content and the extent to which the courses prepared them to perform their TAA job functions. Additionally, respondents will complete a competency check in both courses.

Results: The first collection of evaluation data is set to commence in October 2005 at ERAU in Daytona Beach. We plan to use the data to improve the courses and insure that ASIs are learning the required skills to perform their duties regarding TAA.

Recent Accomplishments: Both course evaluations were developed and designed in scannable forms. Evaluation forms were sent to sponsors for review and comment.

Primary Investigator Carla A Hackworth, Civil Aerospace Medical Institute, Oklahoma City, OK.

Identification of Learning Objectives for Technically Advanced Aircraft

FAA Sponsor Organization: AFS-800

Purpose and Rationale: To identify the knowledge and skills needed to operate a technically advanced aircraft, or any aircraft equipped with advanced avionics. The list of knowledge and skills is intended to serve as the basis for a later technical publication about technically advanced aircraft.

Methodology: The list of knowledge and skills for technically advanced aircraft was derived from four sources:

- Existing FAA technical publications (e.g., AIM, advisory circulars, handbooks, etc.)
- Manufacturer's technical documents
- Scientific literature: observational studies of pilots learning to use advanced avionics;
- A series of focus groups, conducted at NASA Ames Research Center, with pilots, flight instructors, pilot examiners, engineers, researchers, policymakers, and others.

Results: All literature reviews and focus groups have been completed and a final draft of the list of knowledge and skills has been produced. The resulting list contains two types of knowledge and skills for technically advanced aircraft:

- Technical knowledge and skills required for the proficient use of advanced avionics
- Human factors knowledge and skills that focus on the changed role of the pilot in a technically advanced aircraft.

The list of knowledge and skills is a concrete description of teachable and testable line items for use by pilots, instructors, and evaluators. In addition to the list of knowledge and skills, we have prepared two sample chapters of a future publication about technically advanced aircraft. These chapters expand upon individual line items that appear in the knowledge and skills list.

Recent Accomplishment: Finished final report that includes:

- The list of knowledge and skills
- Two sample chapters for a technical publication about technically advanced aircraft.

Primary Investigator: Stephen M. Casner, NASA Ames Research Center

Vertical Flight Research

Program Manager Dr. William Krebs directs vertical flight human factors research that identifies issues associated with helicopter operations within the National Airspace System. It is a relatively new area that addresses certification and regulation of civilian flights with night-vision devices, simultaneous non-interfering operations, and the implications of tilt-rotor controls. Other research areas include head-up displays, low-speed helicopter/power lift displays, and vertical flight instrument flight rules approach lighting requirements.

Human Error Associated with Air Medical Transport Accidents in the United States

FAA Sponsor Organization: Flight Standards Service, General Aviation & Commercial Division

Purpose and Rationale: Helicopter emergency medical services (HEMS) play a vital and growing role in the U.S. healthcare industry. However, since 1998, there has been a troubling increase in accidents associated with this group. Like other aviation platforms, the majority of these accidents are human error related. This investigation used the Human Factors Analysis and Classification System (HFACS) to categorize human error associated with HEMS operations.

Methodology: Data from the National Aviation Safety Data Analysis Center and National Transportation Safety Board were used to identify human-error-related HEMS accidents, specifically medical flights operating under 14 CFR Part 91 (ferrying or repositioning flights) and 14 CFR Part 135 (patient transport). This resulted in identification of 121 accidents, as reported by the NTSB from 1990 to 2003. For the purpose of this report, researchers decided to limit the investigation to only those helicopter accidents (N = 74) occurring in what is termed the "rescue triangle" (i.e., base to the accident scene, accident scene to treatment facility, treatment facility to base). Six pilots served as subject matter experts (SMEs) and read the narratives and tabular data obtained from both the NTSB and the NASDAC to classify each aircrew or supervisory causal factor within the HFACS framework.

Results: Skill-based errors were the most common type of human error in HEMS accidents, followed by decision errors, then violations and perceptual errors. Notably, there were a greater number of fatalities associated with violations when compared to the other unsafe acts. Those accidents, which involved violations, were three times more likely to be associated with a fatality. The highest number of accidents was shown to occur in the en route phase of flight. This is not surprising; assuming that this is the same time that the greatest pressure to "get there" is present. Also troubling were the number of fatalities associated with weather and night-related accidents, as well as controlled flight into terrain (CFIT). To reduce HEMS accidents, technology such as weather displays has the potential for mitigating a serious problem in the EMS industry; namely weather-related accidents and terrain CFITS. Outfitting aircraft for instrument flight, along with insuring IFR currency in the pilot population, would also enhance HEMS safety. Including a second a pilot in the cockpit in Australia and Canada seems to have reduced accident rates in both countries. These are but a few of the measures that the data indicate may benefit HEMS operations. However, perhaps the two most cost-effective interventions also may be two of the easiest to institute. The first is to include training for on-scene responders as standard operating procedure. Law enforcement and ground crews should be educated as to where helicopters can safely land and take off. The second is to reduce exposure to the environment within which the accidents take place.

Recent Accomplishments: Completed Flight Plan Target examination of HEMS data. *Human Factors Analysis of Emergency Medical Helicopter Accidents in the U.S., 1990-2003* was presented at the Air Medical Transport Conference in Cincinnati, OH in October 25-27, 2004.

Primary Investigators: Carla A Hackworth, FAA, Civil Aerospace Medical Institute, Oklahoma City, OK; Bert Boquet, Embry Riddel Aeronautical University, Daytona Beach, FL; Scott Shappell, Clemson University, Clemson, SC.

Investigating ATC Procedures for Simultaneous Non-Interfering Flight within the National Airspace System

FAA Sponsor: Flight Standards Service, General Aviation & Commercial Division

Purpose and Rationale: The overarching objective of this program is to assist in the recommendation of the minimum Required Navigation Performance (RNP) value for a Visual Flight Rules (VFR) helicopter equipped with an IFR Global Positioning System (GPS). The results of this study combined with the output from another project entitled "Helicopter SNI helicopter Flight Data" will assist the Federal Aviation Administration flight standards office in determining the minimum RNP value that will be accepted by the Air Traffic Office in developing procedures for VFR simultaneous non-interfering routes. By correlating human performance data in the simulator to already collected flight data, researchers will be able to further experiment with new flight patterns towards a decreased minimum RNP value. The purpose of the project is to build and validate the simulation system for further experimentation.

Methodology: A critical element of the study involves a model of pilot performance as a factor of pilotage cues (e.g. landmarks) and radio communications (e.g. GPS receivers). Researchers need to know if a pilot fixates on landmarks versus GPS output. Do they simply "fly the needle" off of the GPS unit? Do they carefully observe visual cues, or is it some mix of both? How does this affect the envelope they are maintaining, therefore indicating how traffic can be controlled around them? It is assumed that too much attention to the GPS receiver may adversely affect pilot performance, but that the reverse may also be sub-optimal. The study conducted in this program investigates in a virtual environment simulation how traffic density, workload, and weather affect the minimum RNP for a qualified VFR helicopter pilot equipped with an Instrument Flight Rules GPS.

Results/Recent Accomplishments: The primary accomplishments for 2005 involve attempts to integrate a KLN-89B GPS emulation system in the simulation and writing analysis tools.

Primary Investigator: Rudy Darken, Naval Postgraduate School, Monterey, CA

Video Processing for Analysis of Rotorcraft Navigation Performance

FAA Sponsor Organization: Flight Standards Service, Flight Technologies & Procedures Division

Purpose and Rationale: to determine the ability of pilots operating under visual flight rules to stay within narrow horizontal limits specified by Global Positioning System (GPS) coordinates. In the fall of 2003, a series of flight tests were flown, during which both GPS data and four video streams were recorded, including two streams from a goggle-mounted cameras worn by the test pilot. Analysis of the pilot's gaze behaviors will help to elucidate how perception of out-the-window landmarks interacts with guidance from the GPS receiver (and help explain why navigation performance degrades at night). Additionally, gaze data will confirm that use of the GPS receiver does not prevent scanning of the outside environment sufficient to see-and-avoid other visual traffic. The results will be used to develop guidelines for new regulations and training procedures for the use of GPS systems.

Methodology: The data set from the 2003 flight tests presented several challenges not normally encountered when tracking gaze in the laboratory setting, arising from our inability to completely control the illumination in the outdoor daylight setting. In particular, straightforward application of standard laboratory methods to daytime recordings resulted in gaze estimates for only around 40% of the frames, which was considered unacceptable. We have therefore developed new methods for sorting and classification of the images to permit efficient hand-labeling of a chosen subset, which can then be used for automatic labeling of similar images. In addition, we have constructed a number of interactive software tools to simplify the process of image annotation.

Results: Our new image clustering procedure has been run on both eye and scene camera images for all 15 runs; hand labeling of the eye images has been performed on the first two levels of the eye images (roughly 2000 images). One by-product of the image clustering procedure is an estimate of the intrinsic dimensionality of the image manifold: for the eye images, this has a value of 6. Of the 6 intrinsic dimensions, we can identify 4 with pose parameters: horizontal and vertical gaze direction, pupil radius, and eyelid closure. The procedure and results are described in a forthcoming publication.

Recent Accomplishments: In order to estimate gaze direction from images of the eye, we have abandoned a bottom-up approach based on tracking individual features in favor of a top-down approach based on a geometrical model of the eye in which the inner and outer edges of the iris (known as the pupil and the limbus, respectively) are fit to the image data jointly, resulting in more accurate gaze estimates, especially when the features are only partly visible, as in the illustration above. This approach has an additional benefit that the estimates are obtained in units of degrees, reducing the complexity of the calibration procedure.

Primary Investigator: Jeffrey B. Mulligan, NASA Ames Research Center, Moffett Field, CA.

Air Traffic Control/Technical Operations Research

Under the leadership of Program Manager Dino Piccione, the ATO Air Traffic Control/Technical Operations (ATC/TO) human factors program provides our customers in the ATC operational and system development communities with products that address the capabilities and limitations of humans in the context of ATC systems. These outputs are shaped by the program's research on human performance and other human-system integration issues associated with the concept of operations, system architecture, acquisition, and operation and maintenance of ATC systems. Our simulations and work station prototypes provide a proving ground for advanced concepts to determine their viability in the future National Airspace System in terms of human performance. Improvements in how errors are investigated and reported will foster effective safety interventions. New specifications for the design of TO work stations and displays, and recommendations to improve the communications and coordination process in TO organizations will help to optimize human performance. Continuing research is increasing our understanding of how to effectively deal with regulations associated with work force attrition due to retirement.

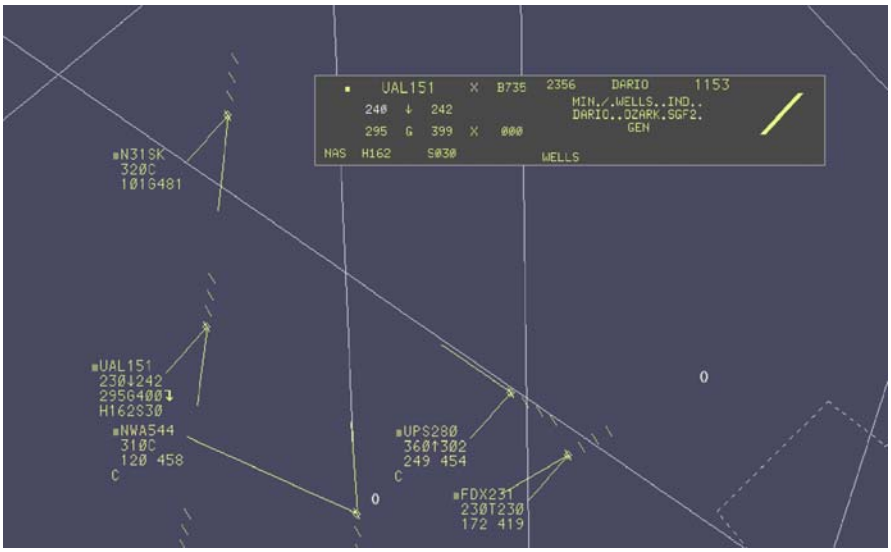
Future En Route Workstation

FAA Sponsor Organization: ATO-E, ATO-P

Purpose and Rationale: Systems engineering of the future En Route Workstation is required to ensure that the workstation is well designed and integrated around the controller's job. Human factors assessments will provide empirical controller performance data that can serve to guide the systems engineering effort. The FAA's En Route Automation Modernization initiative and future en route programs will benefit from having data at hand to guide management decisions on design of the next workstations. The research team will deliver two reports and empirical controller performance data. One report will assess a conflict probe on the Radar-side. The other report will address additional human factors issues of optimizing the workstation.

Method: The approach targets 2015 traffic levels. It is assumed that the FAA will be in the middle of a transition to anticipated capabilities on both the cockpit and ground sides of the system. During previous work, researchers prepared a simulation environment for a fully controlled experiment in which critical information was identified and functionality of existing automation available to controllers in the 2015 NAS target was known. The workstation computer/human interface functionality and display of information was independent of existing automation tools. The future workstation concept's goal is to minimize the amount of time a controller needs to either retrieve data from or input data into the system through application of best human factors principles.

Results: The application of human factors principles to ATC job requirements and the involvement of controllers and programmers has resulted in a simulation infrastructure that can incorporate many of the existing en route automation functions. The current infrastructure has connectivity to automation platforms that include prototypes of the Center TRACON Automation System, the User Request Evaluation Tool (URET), and the Controller Pilot Data Link Communication (CPDLC) system. The infrastructure pulls in automation functions and presents the resulting data in an integrated manner on the Future En route Workstation. Automation functions resulting from early user involvement events with controllers included automatic handoff acceptance, automatic drop-off of data blocks when aircraft leave the sector, more efficient data entry and retrieval (e.g. providing emphasis on aircraft at the same altitude, over the same way point, or at same speed, drag-and-drop data block movement, and depiction of information on the radar display when and where needed (e.g. by providing electronic flight data on the radar display). The data used to depict this information is already available, but isn't used in an integrated manner.



Recent Accomplishment: The study is in the data reduction and analysis phase. The experiment exposed controllers to three workstation concepts and three levels of traffic. Workstation concepts included a baseline condition [Display System Replacement, Traffic Management Advisor, URET, and CPDLC], a generic future concept (identical Radar and Radar Associate workstations), and a specialized future concept (where the Radar and Radar Associate workstations reflected some specialization based on the ATC function). Three traffic levels consisted of 21 (today's traffic), 28 (33% traffic increase), and 35 (66% traffic increase). The experiment included scenarios to address the effect of providing a conflict probe on the Radar Controller Workstation and the effect of upgrading the Data-side display from a conventional configuration to a radar display with integrated automation functions. Finally, the study included scenarios to address the effect of providing data link functionality by removing data link availability. The principal investigator convened quarterly meetings and early user involvement events of controllers to apply human factors guidelines to the development of the experimental workstation.

Primary Investigator: Ben Willems MS, FAA William J. Hughes Technical Center, Atlantic City International Airport, NJ

Weather Information Needs in the TRACON Environment

FAA Sponsor Organization: ATO-T, ATO-P

Purpose and Rationale: Hazardous weather conditions affect the NAS in many ways including flight safety and system effectiveness. Advanced weather information at select Terminal Radar Approach Control (TRACON) facilities is only available to traffic management and supervisors for strategic use. Controllers maintain their Weather Situation Awareness (WSA) by receiving weather briefings from the supervisor and by viewing precipitation levels at their workstation. Providing controllers with display of advanced weather information could be one way to improve the ability of the NAS to deal with adverse weather. However, it is not clear what types of information would be most useful for TRACON operations. This project investigated the benefits and human factors problems associated with the use of advanced weather tools in the TRACON domain.

Method: Eleven TRACON controllers volunteered for the simulation. The research team used a high-fidelity simulator that emulates the Standard Terminal Automation Replacement System. The advanced weather information (AWI) consisted of pre-recorded Integrated Terminal Weather System (ITWS) data presented directly on the TRACON controller workstation (TCW), or on an auxiliary Weather Display System (WIDS) located on top of the TCW. AWI displayed the location and instantaneous movement of storm cells, gust fronts, wind shear, and micro-bursts, and also provided animated predictions of future (15-30 min) storm cell positions. A generic TRACON airspace was used with two adjacent sectors where one controller operated the West sector and the other the East sector. Controllers issued commands to simulation pilots and received additional information from a subject matter expert. During simulation runs, controllers were instructed to keep aircraft away from weather levels 4-6 (*severe weather avoidance*). During all 50-min traffic scenarios, the West side controller wore an oculometer consisting of an eye and head tracking system. Researchers manipulated three variables during the simulation: display

location of AWI (WIDS, TCW and Control), weather scenario (Scenario 1 and 2), and sector position (West and East). The manipulation of display location of AWI resulted in three separate conditions: (1) In WIDS, the team displayed AWI on the auxiliary WIDS display located on top of the TCW (2) In TCW, they displayed AWI directly on the TCW; (3)In Control, no AWI was displayed.

Currently, researchers are conducting a follow-up project of eye movement and workload data. The purpose of this project is threefold: first, to perform in-dept analyzes of workload ratings and strategies for workload reduction; second, to see if eye movement activity measures can be used to predict controller workload levels; and, third, to perform an analysis of fixation patterns and define 'visual areas of interest' from controller weather tool interactions.

Results: A key measure in the present study was the effect on controller efficiency (i.e., sector throughput) from the use of advanced weather information. The result showed that controllers increased the average number of completed flights by 6-10% (TCW and WIDS conditions) compared to Control conditions where no weather information was available. By providing the capability to use static and dynamic predictions of storm movements at the workstation, researchers enhanced a controllers' ability to detect approaching weather, monitor its movement, and understand its effect on future operations. This increased controllers' efficiency for timing of arrivals, flow and sequencing, and runway selection.

Recent Accomplishments: (1) A high-fidelity TRACON human-in-the-loop weather simulation: a technical report, two journal articles, and one paper presented at the Human Factors and Ergonomics Society 49th Annual Meeting; (2) A collaborative project with NASA Ames on the use of color in ATC displays; (3) A project analyzing the relationships between eye movement activity measures and subjective workload ratings and a technical report.

Primary Investigator: Ulf Ahlstrom, FAA William J. Hughes Technical Center, Atlantic City International Airport, NJ

En Route Information Display System (ERIDS) Benefits Study

FAA Sponsor Organization: ATO-P

Purpose and Rationale: ERIDS (En Route Information Display System) is part of the FAA En Route Automation Modernization (ERAM) Plan to replace the current Host computer and backup system. ERIDS is an interactive real-time electronic information display system that was developed to replace the current ATC information display system that uses mostly paper sources of information. ERIDS provides controllers, supervisors and traffic management experts with access to aeronautical data, weather data, airspace charts, ATC procedures documents, Notices to Airmen, pilot reports, and other sources of ATC information. ERIDS is currently deployed and being used by controllers at three Air Route Traffic Control Centers (ARTCCs). Before ERIDS is deployed nationwide, it is important to identify the benefits of the system for controllers at their positions. This study is designed to assess these benefits.

Method: The research team will organize the study by splitting the research into separate components, with two reports as the deliverable products. The first research component will help us to understand sources of information in the current system and how ERIDS operates for access to electronic information. This effort will consist of a cognitive walkthrough with subject matter experts to identify the sources of information in the current system, how frequently controllers access this information, the time and motion required to access information, and how important and current the information is. In addition, we will become familiar with ERIDS by using the system ourselves to determine how easy it is to operate and how much time is required to access electronic information in the system. The second research component will be to collect data at field facilities on how controllers access information in the current system and ERIDS. We plan to observe controllers during live operations, conduct simulations in each facility's training laboratory, and administer questionnaires to controllers.

Results/Recent Accomplishments: (1) Completed a cognitive walkthrough with six subject matter experts. We documented the sources of ATC information controllers use in the current information delivery system, how frequently they access it, and the time and motion required for access; (2) The team completed a test plan for a field study at three ARTCCs. They documented a plan for the data to be collect at these facilities and a method for collecting it.

Primary Investigator: Randy L. Sollenberger, FAA William J. Hughes Technical Center, Atlantic City International Airport, NJ

Tower Electronic Flight Data Handling

FAA Sponsor Organization: ATO-T, ATO-P

Purpose and Rationale: Currently, airport traffic control tower (ATCT) controllers use paper flight progress strips to track aircraft and document ATC changes. With the concept of System Wide Information Management in the Traffic Situation Display, flight information will be available everywhere. A change from paper to electronic flight data would facilitate more timely information on flights being presented to the controller, and will allow entry of timely information. Technology is advancing and electronic flight data are already seen in en route radar facilities as a function of the User Request Evaluation Tool. Researchers will form a workgroup to review the requirements for a prototype ATCT electronic flight data interface (EFDI) and will guide development of prototype ATCT EFDIs. The project will culminate with a set of functional EFDIs and associated documentation.

Method: This study will be a multiyear approach to assess the utility of adding electronic flight data handling capability to the ATCT controllers' environment. The project is linked to the Civil Aerospace Medical Institute (CAMI) field study and future requirements development. In addition to a thorough review of the literature, we will base our work on CAMI findings and recommendations. We will examine flight data information requirements of ATCT controllers as well as integration issues with other flight data elements in order to aid the controller's decision-making. We will form a workgroup consisting of ATCT subject matter experts, software engineers, and engineering research psychologists to provide insight and critical review of information requirements and prototype development. We will document the prototype

development process to record the history of EFDI development. In subsequent years, we will conduct usability tests and human-in-the-loop simulations to directly compare the prototype EFDIs to current paper strips. These future studies will assess the potential for improved controller performance, communication, airport efficiency, information flow, and reduction of workload and errors.

Results: In progress

Recent Accomplishment: (1) Completed literature review; (2) Presented and published results of the literature review at an international symposium on aviation psychology; (3) Established the requirements/prototype development working group; (4) Met with the working group and determined initial requirements for development; (5) Began documentation of development process; (6) Began software development of Airport Surface Detection Equipment-X-band prototype tool in the Distributed Environment for Simulation, Rapid Engineering, and Experimentation initiative to serve as foundation of the EFDIs; (7) Drafted requirements for ATCT simulation platform.

Primary Investigator: Todd R. Truitt, FAA William J. Hughes Technical Center, Atlantic City International Airport, NJ

Final Approach Spacing: An Assessment of Self-Spacing Concepts from the Ground Side

FAA Sponsor Organization: ATO-T

Purpose and Rationale: Future visions of the increasingly congested National Airspace System include concepts in which pilots have the responsibility for merging and spacing their aircraft behind other aircraft. In the terminal environment, pilot self-spacing may enable aircraft to safely maintain minimum separation from leading aircraft, thus maximizing arrival rates to the runway. However, new technologies and procedures will be required to support the implementation of these concepts. This project was designed to assist in developing a successful air traffic controller workstation that will support pilot self-spacing operations.

Method: There were three elements of the research methodology. First, researchers participated in an international work group to define applications of available technology to enable pilots to perform self-spacing operations. Second, the researchers collected and reviewed literature related to pilot self-spacing, with the focus on identifying issues that require additional research, especially in the terminal environment. Third, the researchers began developing a test plan to address those issues.

Results: The international workgroup and other organizations (e.g., MITRE, NASA) are still refining numerous applications, three of which are particularly relevant to this project: (1) Cockpit Display of Traffic Information (CDTI) Assisted Visual Separation; (2) Enhanced Visual Approach; and (3) Visual Separation on Approach. All three applications call for pilots to use onboard CDTIs to identify traffic to follow and to maintain a prescribed spacing from the lead aircraft. They involve little or no change to current procedures and require only basic CDTI capability on the flight deck. Although the research on pilot self-spacing has focused on en route,

the available literature indicates that pilot use of a basic CDTI assists in visually acquiring traffic and that following the lead aircraft is beneficial. Pilot workload is generally acceptable, and controller reaction to these procedures has generally been positive. The more advanced applications would require modifications to current procedures, more sophisticated CDTI capabilities, and additional controller workstation tools. The results of most studies on these applications indicate that the advanced concepts are not mature and require further development before they become feasible. Therefore, the researchers consider it premature to plan additional work on the controller workstation until the concepts are better defined and their viability better demonstrated.

Recent Accomplishments: The research team has collected and reviewed over 80 reports and documents related to pilot self-spacing, and have held discussions about the concepts with numerous researchers in the field. A draft literature report was submitted for sponsor review in 2005. A technical report (*Pilot-based Spacing and Separation on Approach to Landing: The Effect of Air Traffic Controller Workload and Performance*) was prepared.

Primary Investigator: D. Michael McAnulty, FAA William J. Hughes Technical Center, Atlantic City International Airport, NJ

Air Traffic Control Tower Modular Display Systems

FAA Sponsor Organizations: ATO-P, ATO-T

Purpose and Rationale: In the air traffic control tower, there are numerous displays presented in configurations that are not standardized across control towers. The accumulation of displays, the lack of integration of the information presented across displays, and the lack of standardization have led to costly maintenance programs and potentially reduced operational safety and efficiency. An alternative approach is to determine the tower controllers' information needs and present this information in displays that are integrated and positioned in the tower with consideration of human factors principles. The need for standardization needs to be addressed to reduce the overall cost to implement and maintain tower systems. This involves identification of a core module of displays essential to all towers as well as additional modules of displays tailored to various tower operational characteristics. These modules may be determined based upon the controllers' information needs and classes of towers as a function of airport size, runway configuration, traffic level, traffic mix, staffing, and airspace layout.

Methodology: Tower controller information needs and associated task flow diagrams will be developed and validated through observations of tower controllers at a minimum of five Category X airports. The controllers' sequential scan patterns will also be observed to determine the sources of information used today in controlling surface traffic. Tasks that are common across these towers as well as those tasks that are unique to these towers will be identified and extrapolated to other towers in the National Airspace System. Classes of towers will be identified based upon controller information requirements and tasks, the information sources, and airport operational characteristics. Modules for tower displays and candidate presentations of the information to enable an efficient scan pattern will be developed using the information requirements, tasks, and classes of towers.

Results: In progress.

Recent Accomplishments: Preliminary ground and local controller task flow diagrams have been completed. Tower visits are currently being coordinated.

Primary Investigator: James Hitt, Booz Allen Hamilton, McLean, VA

Optimizing Human Performance through Training

FAA Sponsor Organization: ATO-A

Purpose and Rationale: Because of the continually evolving nature of the ATC system, projected increases in traffic levels, and enhanced system capabilities, the controller's task-load and performance are critical concerns. As the environment becomes more automated, mental demands on controllers may also change. Techniques are needed for enhancement and maintenance of the basic skills that support expert air traffic control performance to mitigate performance degradation. Developing better training techniques is critical to developing and maintaining a skilled workforce of air traffic controllers.

The NATPRO Concentration program was developed and evaluated by FAA operational controllers. By combining a two-hour class with fifteen practice sessions, it integrated knowledge- and skill-based training. Air traffic management concurred at the outset that everyone who maintains operational currency should receive the training and should complete the program by December 2005. The FY 2005 goals were to (a) support air traffic operations' delivery of the NATPRO Concentration program to determine whether a skill-based approach to air traffic controller training improves operational performance, and, (b) complete a development plan for a second NATPRO program on the topic of read back-hear back errors.

Methodology: The skills training suite was installed in computer laboratories in twenty-one en route facilities. A team from each facility was trained to deliver the program at their respective facilities. Performance data from facility participants were uploaded to a central server. CAMI researchers provided administrative and logistical support.

Results: In FY 2005, training of facility personnel to deliver the program was completed and the server infrastructure of the program was improved. Several software improvements to the skills training suite were also made. Because the program will end on December 31, 2005, program assessment will begin when the database is complete.

Recent Accomplishment: Development of a second training program for read back/hear back errors is underway and is planned to be in draft form by February 2006.

Primary Investigator: Julia Pounds, Civil Aerospace Medical Institute, Oklahoma City, OK

Optimizing Human Performance to Reduce Runway Incursions

FAA Sponsor Organization: Air Traffic Office of Safety Services (AJS)

Purpose and Rationale: This project responds to the FAA Safety Goal to "Improve training, procedures, evaluation, analysis, testing, and certification to reduce the risk of runway incursions resulting from errors by pilots, air traffic controllers, airport authorized pedestrians, vehicle operators, tug operators, and mechanics conducting aircraft taxi operations." Developing knowledge about causal factors leading to runway incursions is critical because of the continued evolving nature of the aviation system. Increasing traffic levels and enhanced system capabilities, which are being developed and fielded to alleviate traffic load and increase traffic efficiency, could impact the controller and pilot's task-load and performance. The purpose of this research was to better understand the role of individual, situational, and work-related factors as they influence the operational performance of air traffic controllers, pilots, and ground operations personnel. Outcomes will be used to develop interventions based on human factors principles for enhancement of performance and to improve overall safety.

In FY 2005, the goals of this research were to: (a) refine the JANUS technique as a tool to identify factors leading to pilot deviations; (b) test the technique using archival reports of pilot deviations in preparation for simulation studies and field data collection activities; and (c) refine causal factors in the JANUS technique for controllers by continuing data collection at terminal facilities.

Methodology: Materials from the JANUS technique for ATC were used. Causal factors used by the National Transportation Safety Board for pilot incidents were matched with JANUS categories. This JANUS-FLT model was then reviewed by subject matter expert pilots with experience in Parts 91, 135, and 121 operations. They further elaborated the materials to better reflect potential factors relevant to these aviation environments.

Results: A draft of JANUS–FLT was completed which reflected possible causal and contributing factors in Parts 91 (recreational and instructional), 135 (air taxis and business jets), and 121 (scheduled and non-scheduled) operations. A test of the model using archival deviation reports was not conducted due to loss of research staff from the project.

Recent Accomplishment: Pilot subject matter experts developed JANUS–FLT materials. A briefing was provided to representatives from the Airline Pilots Association.

Primary Investigator: Julia Pounds, Civil Aerospace Medical Institute, Oklahoma City, OK

Historical Assessment of ATC Human Factors of Operational Errors

FAA Sponsor Organization: AJS-0, AJS-43

Purpose and Rationale: This study was designed to review the existing research literature on operational errors (OEs) and OE intervention strategies as a means of identifying mitigation strategies for immediate deployment. Outcomes will be used in support of the FAA Air Traffic Organization's goal of reducing operational errors.

Methodology: We first conducted a review of the scientific and technical literature and identified 154 documents covering a 45-year time span from 19960-2005 that addressed aspects of operational errors. We used two approaches the classifying the material, one based on the type of study and the second involving a human factors categorization using the JANUS taxonomy. Secondly, we identified 197 OE prevention and reduction initiatives. That information was also classified using the JANUS taxonomy. The information gained from this approach allowed us to identify knowledge gaps in both the research studies and error reduction initiatives.

Results: This review has shown that much (sometimes redundant) research has been done but has generated little new information about why OEs occur. An additional roadblock is that the information currently collected as part of the OE investigation process is incomplete from a human factors perspective. This has restricted the ability of researchers to identify the underlying causal factors and their interactions. Similarly, many initiatives have been implemented, but the lack of a systematic follow-up has prevented us from learning which were effective.

The tendency to conduct similar research and to implement similar interventions will continue unless steps are taken to: (1) obtain relevant data to conduct more informative, theory-based analyses; and (2) continually assess the effectiveness of OE mitigation strategies. In the years to come, scientists will monitor research efforts and operational initiatives to avoid "reinventing the wheel" (repeatedly conducting the same analyses and initiatives) and "picking the low hanging fruit" (continuing to address apparently easy problems). This will help develop a safety culture by obtaining better data about the circumstances surrounding OEs and identifying the relative importance of individual, supervisory, and organizational contributions.

It is proposed that a workgroup consisting of members of both the operational and research communities be convened to address the following recommendations: (1) Expand OE data available for analysis to better identify the human factors associated with OEs, collect additional baseline information on normal operations, and develop objective measures of controller performance; (2) Research and analyses could be improved by identifying the high impact causal factors, accounting for the interactive nature of factors that lead up to an OE, and examining OEs in the context of an overall safety culture; and (3) Develop improved approaches to monitor and evaluate the outcomes of OE intervention strategies.

Recent Accomplishments: A final report entitled "A Human Factors Review of the Operational Error Literature" was delivered to ATO-P R&D.

Primary Investigator: Lawrence L. Bailey, Civil Aerospace Medical Institute, Oklahoma City, OK

Operational Error Time Vulnerability Study

FAA Sponsor Organization. ATO Vice President of Safety

Purpose and Rationale: The FAA's ATO has a performance goal of reducing the number of Category A and B (most serious) Operational Errors (OE) to no more than 563, equivalent to a rate of 3.18 per million activities. Despite a long history of identifying the human factor causes of OEs and implementing mitigation strategies for reducing their occurrence, thus far nothing has been able to reverse the trend - as the number of aircraft in the National Airspace System increases, so do the number of OEs. A need exists to understand why past interventions have not been effective at reversing the OE trend. Of specific concern is why do OEs occur during the first 10 minutes after a change in position, despite repeated efforts at improving the position relief briefing,? Towards addressing that concern and others related to specific "on position" OE time vulnerabilities, a Time Vulnerability Study (TVS) was conducted.

Methodology: Five research objectives govern the TVS: (1) determine the human factor issues related OEs occurring during the first 10 minutes on position; (2) identify the strength and weaknesses of past interventions designed to reduce OEs occurring during the first 10 minutes on position; (3) develop an OE action plan for reducing the most likely human factor causes of OEs occurring during the first 10 minutes on position; (4) develop metrics for tracking the effectiveness of OE reduction efforts targeted at reducing OEs occurring during the first 10 minutes on position; and (5) providing education material to highlight the human factor vulnerability associated with the first 10 minutes on position.

Results*:* The technical approach is divided into three phases: (1) the problem identification phase; (2) the problem mitigation phase; and (3) the problem intervention phase. In the problem identification phase, three sources of information will be used to construct an initial understanding of controller vulnerabilities during the first 10 minutes on positions: (1) review of historical FAA records concerning transfer of position procedures; (2) cognitive task analysis of controller performance during transfer of position; and (3) OE database information about the first 10 minutes on position with a focus on the position relief briefing. Database narratives associated with OEs that occurred during the first 10 minutes will be used by trained ATC subject matter experts (SME) to identify factors that contributed to the OE. In the problem mitigation phase, the output generated from the previous phase will be presented to ATC SMEs from the field who will then assign priorities to each issue using a structured ranking system based on operational feasibility and operational impact. In the problem intervention phase, the most promising strategies for decreasing controller vulnerability to OEs occurring within 10 minutes on position will be presented in a multi-media format to be used as field training material. Metrics for tracking the effectiveness of field training will include the reduction of OEs occurring during the first 10 minutes on position that were associated with the topics addressed during training.

Recent Accomplishments: A briefing package describing the results of the initial study was completed in FY 2005.

CAMI Primary Investigator: Larry L. Bailey, Civil Aerospace Medical Institute, Oklahoma City, OK

Intra-Team Communication

FAA Sponsor Organization: Risk Reduction Projects Group, (AJS-42)

Purpose and Rationale: The ATO Safety Office has a goal to reduce the number of runway incursions attributed to a lack of coordination/communication between ground and local control controllers. Runway incursion report forms do not provide enough details about the coordination between ground and local controllers during the reported incident. Thus, there is a need to develop a better understanding of the communication and coordination between ground and local control controllers. Based on knowledge of neuropsychology and cognitive psychology, the purpose of this project was to develop a classification system to describe the cognitive disruptors of effective local and ground control intra-team communication and coordination.

Methodology: Tower observations and published literature were used to develop a framework for understanding the dynamics associated with local and ground control intra-team communication and coordination. Narrative information about local and ground control intra-team communication and coordination was extracted from the operational error (OE) database. A classification system was developed from OE narrative reports to identify potential cognitive disruptors associated with local and ground control intra-team communication and coordination.

Results: Seven potential cognitive disruptors were identified:

- Goal Interference – when accomplishing one task interferes with the accomplishment of another
- Similarity Confusion – trying to differentiate between two highly similar objects
- Proactive and Retroactive Interference – when the knowledge from past experience interferes with the processing of new knowledge, and vice versa
- Attentional Blink – information that is lost when the second of two pieces of information is presented less that one second after the first piece of information
- Attentional Blindness – when one part of the visual field is not processed
- Memory Consolidation – incomplete memory consolidation due to distraction
- Episodic Memory Overload – when the memory capacity is exceeded at a given point in time

Although any of the seven disruptors may interfere with effective ground and local control communication and coordination, the results suggested that problems with attentional blindness, memory consolidation, and episodic memory overload occurred most frequently. However, since the classification of cognitive disruptors was based on inferences drawn from a retrospective analysis of OE narratives, future research needs to be conducted in an experimental setting (using an ATC tower simulator) before a more definitive statement can be made about the effects of cognitive disruptors on aviation safety.

Recent Accomplishments: In FY 2005, the research team delivered a final briefing to the sponsor and presented two scientific papers on the research results.

Primary Investigator: Larry L. Bailey, Civil Aerospace Medical Institute, Oklahoma City, OK

Normal Operations Safety Survey (NOSS):
Adapting the Line Operations Safety Audit (LOSA) Methodology to Air Traffic Control (ATC)

FAA Sponsor Organization: Air Traffic Services

Purpose and Rationale: Researchers at the University of Texas are working to develop and promote NOSS and the Threat and Error Management (TEM) framework in ATC. NOSS is a tool designed to collect safety information for Air Navigation Service Provider safety management systems.

Methodology: NOSS is an extension of LOSA methodology, which is a non-jeopardy, over-the-shoulder observation methodology for monitoring normal operations. Based on the TEM framework, NOSS captures controller performance and the operating context in which it occurs. Incident reports and subject matter experts (SMEs) from the International Civil Aviation Organization (ICAO) NOSS Study Group were consulted in developing observation protocols and threat and error categories.

Results: Initial data collection forms, observer training curricula, and threat and error taxonomies have been developed by reviewing incident reports and consulting SMEs. Two NOSS trials were conducted during the summer of 2005 by Air Services Australia and Airways New Zealand, at their own expense, in partnership with the University of Texas to assess the NOSS materials. The results of the trials demonstrated the feasibility of the NOSS concept in ATC and were presented to the ICAO NOSS Study Group in November, 2005. Adjustments will be made in the NOSS methodology based on the lessons learned from the trials.

Recent Accomplishments: In the past year, researchers have contributed to the development of a circular on TEM in Air Traffic Control, which is currently under review by ICAO. Findings from the two NOSS trials have been presented to senior management at Air Services Australia and Airways New Zealand. The researchers presented findings at the 3rd ICAO/IATA LOSA/TEM conference which was held in Kuala Lumpur in September 2005. The research group is in the process of comparing NOSS and LOSA findings to maximize the benefit of future data collection on pilot/ATC interactions. This integrated approach will facilitate in the sharing of NOSS/LOSA data by airlines and ATC providers.

Primary Investigator: Robert L. Helmreich, University of Texas, Austin, TX

Runway Incursion Severity Categorization (RISC) Model

FAA Sponsor Organization: ATO-S

Purpose and Rationale: Severity ratings for runway incursions are assigned by a group of FAA subject matter experts (SMEs). While the group decision process has the advantage of combined areas of expertise, it also has inherent sources of rating variability. The two most notable sources of variability are the personal criteria for risk acceptance (that is, some individuals were generally more conservative than others), and shift of the group's criteria over time. The goal of an automated system for rating the severity of runway incursions was to model the expertise of the group (in terms of the knowledge base and decision processes) in a consistent (and thus reliable) fashion.

Methodology: A computer model was developed that categorizes the severity of the outcome of a runway incursion. The model uses the same decision-making process that the SMEs use. That is, it starts with a description of the event that resulted in the incursion and the reported closest proximity, and then considers the effect of visibility, aircraft type and avoidance maneuvers, and the degree of control that pilots and/or controllers had in the situation. The model was validated by comparing the results of the group's assessment to the model's ratings for the same event.

Results: In FY 2005, validation of the computer model continued as FY 2004 events were included. Runway incursions from FYs 2002, 2003 and 2004 have also been processed though the model. The Office of Runway Safety and Operational Services was briefed on the overall agreement between the model's results and the group's results. In the same meeting, a sample of events in which the model's rating differed from the group's ratings was discussed. Based on the results of that meeting, the logic of the model has been revised and validation continues. Other current activities include refinement of the user interface, revising the programming code to make the program more robust, and continuing to refine the program logic.

Recent Accomplishments: Having been used in "shadow mode" in FY 2005, the model is now being used in "real time". In FY 2005, the FAA has been using the model to rate runway incursions and comparing – on a weekly basis - these ratings to the results of the group assessment. (Note: the assessment team was not informed of the results before their meeting.). Now, the model is being used in real time - the FAA is able to obtain a rating from the model before the group's weekly assessment meeting so that the model's rating can be validated by the group.

Benefit to FAA. Use of the RISC model will benefit the FAA in several ways. First, it provides a more structured (and thus, more defensible) approach to the task of categorizing of the severity of runway incursions. Second, it provides an automatic count of the various scenarios (e.g., crossing in front of a takeoff) that describe runway incursions. This frequency distribution of runway incursion scenarios is useful in examining relative risk. Finally, it is anticipated that this tool will be offered by ICAO to member states as a method to categorize the severity of runway incursions as a means of supporting international collaboration on safety analysis and development of mitigation strategies.

Primary Investigators: Kim Cardosi, Thomas Sheridan, and Daniel Hannon, DOT/Volpe Center, Cambridge, MA

Development of Human Error Analysis Tool

Sponsor: ATO-P Human Factors Research and Engineering

Purpose and Rationale: The purpose of this project is to develop a human error analysis methodology that will allow FAA human factors practitioners to "predict" the likelihood and severity of human errors associated with maintenance tasks for Air Traffic Control systems and facilities. Providing the ability to predict a human error prior to its actual occurrence will significantly enhance the safety of the National Airspace System (NAS).

Methodology: Researchers are adapting a methodology called Human Error and Safety Risk Analysis (HESRA) to meet the needs of the FAA. HESRA is a human error analysis approach that is based on a Failure Modes and Effects Analysis (FMEA). While FMEA focuses on component failures, HESRA focuses on tasks, steps, and the associated human errors that can occur for each task and step. Errors are rated, using ordinal scales, in terms of likelihood of occurrence, severity of the consequences of the error, and the likelihood of detecting and mitigating the error. These ratings are used to calculate a Hazard Index (HI) and a Risk Priority Number (RPN). This allows the FAA to do a rough rank order of risks and address the most critical.

The research team is adapting HESRA through the following tasks:

- Researching the environment
- Developing the methodology
- Applying the methodology to a target system
- Revising the methodology based on the results of the application.

At the end of FY 2005, they completed a draft of the methodology to take into the next year. Next year's activities will include:

- Applying the methodology to a developmental system
- Developing an approach for prioritizing maintenance procedures and/or task sequences to focus on the most critical ones
- Validating the methodology
- Publishing the final methodology.

Results: To date, researchers have developed an initial draft methodology, applied it to the Voice Switching Control System, and revised the methodology based on the results of the application.

Recent Accomplishments: Researchers conducted a workshop at FAA headquarters to introduce the methodology to the FAA human factors community.

Primary Investigator: Larry Avery and Michael Maddox, HumanCentric Research, Cary, NC

Safety Culture in Air Traffic Operations:
Assessment, Intervention Development, and Transfer of Best Practices

FAA Sponsor Organization: ATO-P, Human Factors Research

Purpose and Rationale: The Air Traffic Organization (ATO) is committed to building a robust safety culture throughout its organizational units. In order to accomplish this task, it is essential to define the desired safety culture as it applies to the air traffic environment, measure the extant safety culture, develop appropriate intervention strategies, implement those interventions, measure the effects of such interventions, and ultimately multiply such positive transformations throughout the ATO system. Issues such as developing and sharing best practices, employee-management trust, goal sharing, error management/reporting, training, etc. are being examined. This project does not address personal injury/bodily harm issues that are under the purview of the Occupational Safety and Health Administration. However, the effectiveness of *mechanisms* associated with reporting hazards and improving the work environment will be addressed. Emphasis is on *transformation* of the safety culture.

Methodology: As of September 2005, the project team had conducted two focus-group discussions across a representative sample of the Technical Operations workforce—employees as well as management and a reasonable variety of specialty groups/work environments. The researchers will continue with at least two more focus-group discussions in FY 2006. The results from these discussions will feed into a questionnaire that will be distributed to the participating units/departments. Based on the results of the focus group discussions, survey analysis, and post-survey discussions, the project team will collaborate with the partner sites to develop appropriate interventions to improve the safety culture at that site. Interventions such as training, facilitation, or specific recommendations will need to be implemented. A post-implementation survey will measure the effects of the interventions. Effective innovations and best practices will be shared with other ATO units.

Results: A typical Technical Operations Specialist who is responsible for maintaining a particular ground-based communication or navigation equipment suite appeared to be extremely proud of his/her job. and had a strong sense of ownership of the equipment for which he/she was responsible. There seems to be some evidence of deterioration in the safety culture, especially at local-to-regional-headquarters boundaries and in the context of the ongoing organizational changes in the ATO. The next two focus-group discussions and the follow-up survey will elaborate further on these issues.

Recent Accomplishment: The research team is working with the Technical Operations Human Factors Safety Team (TOHST) to gain access to various field sites. The research team is also connected with the ATO Transition Team. Therefore, the efforts of this team are fully coordinated and complementary to other ongoing research and development efforts.

Primary Investigator: Manoj S. Patankar, Saint Louis University, St. Louis, MO

Human Factors Issues for Collaborative Decision Making (CDM) in the National Airspace System (NAS)

FAA Sponsor Organization: ATO-P

Purpose and Rationale: One of the more powerful concepts to emerge from the CDM program for expediting departures has been the idea of dealing with dynamic weather and traffic constraints by pre-planning a flight to accept alternative Coded Departure Routes (CDR). This technique makes it possible to delay the decision about what route to fly until an aircraft taxis out. The concept is being applied at a number of airports. However, the current practice has two major weaknesses: (1) frequently, there is not adequate advance notice when alternative routes may be offered to a flight; (2) and when there is advance notice, it is often not sufficiently specific, resulting in a need to add extra fuel to the aircraft. There are three potential results that are undesirable: (1) departures may be delayed because the flight crew has to first contact dispatch to determine whether the offered route is acceptable (or needs additional fuel); (2) the flight crew may simply accept the offered alternative route, leaving dispatch out-of-the-loop; or (3) the flight may be pre-planned and fueled for more CDRs than actually necessary to deal with the constraint. Based on these considerations, the objective of this research is three-fold:

- To develop methods to improve communication between FAA traffic managers and dispatchers working at flight control centers regarding the dynamic use of CDRs at an airport
- To design and prototype tools to evaluate the actual use of coded departure routes
- To improve the design of CDRs to increase their usefulness
- The ultimate goal is to develop tools that improve the effectiveness of this process for expediting departures while keeping dispatch in the loop to ensure safety.

Methodology: Structured interviews and focus groups were held with traffic managers and dispatchers to understand the nature of this problem and to evaluate alternative solutions. In addition, pilot studies were conducted to evaluate one approach to improving communications and to explore the use of CDRs by general aviation (GA) aircraft. Two post operations evaluation tool (POET) summary reports were prototyped to help evaluate the use of CDRs.

Results: The findings supported a number of recommendations to improve the use of CDRs: (1) the need to improve data consistency in the CDR databases; (2) develop CDRs for RNAV-equipped aircraft; (3) inhibit PDARs when CDRs are in use; (4) develop a memorandum of understanding for use of CDRs; and, (5) provide objective feedback on the use of CDRs. The findings also provided direction regarding new methods for communicating the potential dynamic use of CDRs, and the potential value of including GA flights in the use of CDRs and other pre-coordinated plans. This work provides guidance on the use of coordinated contingency planning as a strategy to enhance distributed work.

Recent Accomplishments: The findings have resulted in –

- Development of a change proposal for the FAA Order defining the use of CDRs
- Changes in the training of staff in order to ensure the inclusion of greater detail about the potential dynamic use of CDRs during operations planning meetings.
- Development of two POET summary reports, one to provide monthly information on the use and impact of CDRs for an airport, and the other to provide more detailed information about a flight that has been impacted by the use of a CDR (or some other traffic management initiative).

- Preparation of a report to the CDM Steering Committee and ATC staff recommending methods for improving communication about the potential dynamic use of CDRs.

Primary Investigator: Philip J. Smith, the Ohio State University, Columbus, OH

Human Factors Issues of Achieving the Target System Description

FAA Sponsor organization: ATO-E, ATO-P

Purpose and Rationale: Both the FAA and the RTCA Commission have presented views of the future ATC system in the 2015 time frame. The FAA needs to identify human factors issues and examine enabling concepts to make the transition to the future vision of the National Airspace System (NAS) established in the Target System Description (TSD). Understanding gaps in knowledge will ensure that we can successfully mitigate problems before they arise. We will deliver a technical note that maps the human factors issues and enabling concepts onto the current TSD vision of the NAS.

Method: Researchers on this project will conduct an in-depth examination of the future of the NAS. They will examine written documents on these views and identify human factors issues and enabling concepts to be considered as we transition to the future. Through a rigorous, analytical approach, they will work to uncover the human performance dependencies embedded in moving from the current system to the future, as well as enabling pathways through automation, workstation design and job design. The impact of operational improvements on human performance factors will be identified, and human factors strategies for system design will be mapped to mitigate the potential for excessive workload or information overload. In addition, the research team will collaborate with headquarters, CAMI, and Volpe to incorporate their assessments of human factors issues such that this work may serve to support evolution of the ASTO-P R&D ATC research program.

Results: A technical note summarizes the human factors impact of advanced concepts on ATC. The technical note suggests that over the next decade, NAS modernization will result in profound changes for all NAS users and service providers, including the surface, terminal, en route, and oceanic domains. The purpose of the report is to identify human factors implications of new technologies and processes on air traffic controllers early in the development cycle. The report includes four sections: a description of core controller tasks, upcoming enhancements for each of the NAS systems, human factors implications of these enhancements, and the effect of these changes organized by key human factors subject areas. Core controller tasks include maintaining situation awareness, developing and receiving control information, making decisions for control actions, solving aircraft conflicts, providing tactical air traffic management, and performing complementary tasks. Enhancements to the NAS will require fundamental changes in the way controllers perform these tasks. The document summarizes some primary human factors aspects that system designers should be aware of when implementing changes to the NAS. As traffic levels increase, automation will need to provide controllers with the necessary tools to alert them to situations that need their attention and to filter the data they need for decision-making. Technology alone will not be able to support these increased capacity demands. To meet these demands, we need to rely on a combination of technology and the human operators in the system.

Recent Accomplishment: A FAA Technical Note is in preparation and submitted in draft to the sponsor to document the human factors issues and enabling concepts.

Primary Investigator: Ben Willems, FAA William J. Hughes Technical Center, Atlantic City International Airport, NJ.

Dynamic Resectorization

FAA Sponsor organization: ATO-E, ATO-P

Purpose and Rationale: Current airspace structure is rigid and does not allow for flexible dynamic boundary adjustments. Dynamic resectorization of airspace boundaries is adaptive and can efficiently handle heavy traffic situations, shifting weather conditions, status changes in special use airspace, and user-preferred routes. Future concepts for the National Airspace System propose unlimited dynamic resectorization to reduce aircraft delays, decrease fuel consumption, and lower operating costs for the airline industry. However, dynamic resectorization may not be effective for all traffic situations. It is important to identify situations where dynamic resectorization may be beneficial and situations where it may be disruptive, as well as alternatives to dynamic resectorization. This will allow Air Traffic Control to maximize use of finite airspace as traffic patterns demand by offsetting heavy workload. This will increase safety and capacity.

Method: There are different approaches to implementing dynamic resectorization using current and future technologies. Concepts range from the current limited practice of coordinated exchange of airspace by Terminal Radar Approach Control (TRACON) and Air Route Traffic Control Centers into large TRACONS during particularly heavy arrival times, to completely dynamic remapping of the airspace at any time. Some methods may be less disruptive and more effective than others. Researchers conducted a literature review on the current status of the dynamic resectorization concept by examining the past few years of research conducted by MITRE, MIT Lincoln Laboratory, and others.

Results: The literature review demonstrated the current applications of dynamic resectorization and identified human factors issues. Controllers organize their work around predictable structure in their airspace, rules and procedures. Therefore, we need to build tools and procedures to maintain the cognitive structures for controllers as we develop the concept of dynamic resectorization further.

Recent Accomplishment: This project resulted in a report with recommendations for an approach to assess dynamic resectorization based upon empirical data. An FAA Technical Note is in review.

Primary Investigator: Pam Della Rocco, FAA William J. Hughes Technical Center, Atlantic City International Airport, NJ

Human Factors Design Standard Update Plan

FAA Sponsor Organization: Technical Operations

Purpose and Rationale: The Human Factors Design Standard (HFDS) is a comprehensive reference document used throughout the FAA to promote good human factors principles in the design and procurement of systems. One key to making the HFDS a valid reference source is keeping the document current and aligned with the FAA's needs. To do this, the document is updated regularly, on the order of one chapter per year. Maintaining the HFDS has always been an informal process. One of the goals of this effort was to establish a formal process for the maintenance of the HFDS. Another goal of this effort was to identify criteria that could be used to prioritize chapter updates. In addition, this effort examined FAA goals and user feedback to project future needs for the HFDS.

The value of the HFDS to the FAA is unquestionable. Every day, people in the FAA and across the airspace industry have to make hundreds of different design decisions. These decisions impact the ultimate safety, effectiveness and efficiency of airspace systems. Program managers within the FAA want to have the best system possible, yet are faced with time and budget constraints. FAA managers do not have the time or resources available to research every human factors design concern facing their program. By providing a single, easy-to-use reference source, users can quickly find answers to human factors design questions. The HFDS goes beyond being a reference source because it is a design standard. The information within the HFDS is written in "should" or "shall" statements, allowing the HFDS to be used as a resource for communicating system requirements. A formal plan for maintaining this document is necessary to facilitate its future usefulness.

Method: Researchers analyzed FAA planning documents to identify systems and equipment that are planned for development or procurement. They used these planning documents as a basis of aligning priorities for information with the mission and goals of the FAA. A high level analysis of the systems was performed to identify what human factors areas are relevant to that program. Primary users of the HFDS were identified and interviews were conducted to determine their needs and priorities. This information was used to develop a plan for maintaining the HFDS.

The researchers also reviewed information on past users of the HFDS. The William J. Hughes Technical Center's Human Factors Group maintains a database of users who have either requested CDs or downloaded the HFDS. The database contains information on the country, type of organization, and the intended use of the information. Although these fields are voluntary, a full two-thirds of those requesting or downloading the document provide this information. The researchers analyzed this database to categorize the users of the HFDS and determine, where possible, what the HFDS is currently being used for. The researchers also supplemented information from the database by performing more in depth interviews with a subset of users. Users were identified to determine their needs and priorities through structured interviews or a survey. Because of financial limitations, structured interviews were limited to those users who were easily accessible to the researchers. The results of these steps were integrated into a strategic management plan for the HFDS.

Results: This effort resulted in a technical report titled *Human Factors Design Standard Maintenance Plan.*

Recent Accomplishments: This effort was reviewed and cleared for publication by ATO-P at FAA headquarters.

Primary Investigator: Vicki Ahlstrom, FAA William J. Hughes Technical Center, Atlantic City International Airport, NJ

The Design of Alarm Lists for Maintenance Monitoring, Filling the Gaps in an Alarm Standard

FAA Sponsor Organization: Technical Operations

Purpose and Rationale: One of the primary tasks performed by National Airspace System (NAS) maintenance personnel is the monitor and control of equipment. When equipment goes out of a predetermined tolerance level, visual and auditory alarms indicate to the user a condition in need of action. Previous research performed by the William J. Hughes Technical Center (WHJTC) pulled guidelines from various sources to create a draft alarms standard. In creating this standard, researchers discovered several gaps in the literature that caused them to be unable to provide guidance in several key areas of the auditory alarm draft standard. Additional analyses are necessary to answer specific questions about alarm issues unique to the NAS environment, particularly issues related to alarm display lists. The purpose of the research project is to address these questions by performing a set of experiments aimed at filling the gaps in knowledge related to alarm list display and integrating these findings into a more complete and useful alarms standard for NAS systems. This research addresses issues of alarm design for alarm list displays. The main goal is to standardize alarm list design based on empirical evidence.

Method: Three small-scale personal computer-based experiments will be conducted by the WJHTC Human Factors Group aimed at identifying optimal parameters for alarm list display for NAS systems. The experimental displays will focus on specific aspects of monitor and control list displays and will not try to simulate a realistic monitor and control system. Users will not be asked to perform monitor and control functions. Instead, the tasks will involve reaction time and recall based on lists of information.

Researchers will have programs specifically developed for collecting data on alarm list display features. Twenty participants will be sought for each experiment. The oculometer will be used to measure eye movements. Specially designed data collection software will be used to collect reaction time data. Results from this study will be used to develop recommendations on ways to optimize list design. These results will be published in a final report.

Results: This is an ongoing project. The result of this project will be used to optimize list format, potentially reducing errors and increasing efficiency for the NAS.

Recent Accomplishments:

- Conducted literature review
- Created Institutional Review Board material
- Received Institutional Review Board application approval
- Conducted familiarization site visits
- Created data collection materials

- Conducted study shakedown

Primary Investigator: Vicki Ahlstrom, Federal Aviation Administration (FAA), William J. Hughes Technical Center, Atlantic City International Airport, NJ

Communication of NAS System Status between AT and Technical Operations

FAA Sponsor Organization: Technical Operations

Purpose and Rationale: Currently both Air Traffic (AT) and Technical Operations (TO) personnel have some responsibilities in communicating the status of NAS equipment, both through phone calls and data entries in logging software. Anecdotal evidence indicates that a certain number of these efforts are redundant. Reducing redundancies could improve efficiency and reduce workload. However, we don't currently know where there are redundancies. This study will identify the redundant communication of NAS status. The potential benefit of this study will be more efficient communication and coordination between TO and AT, and a reduction of unnecessary workload. The outcome of this study will be a technical note detailing the results of the study and a briefing to the sponsor describing the results and identifying where there are redundancies in the communication of NAS status.

Method: This study will examine communications between TO and AT, specifically communications related to equipment status. Researchers will review current procedural documents which set the guidelines for communicating system status. Researchers will also examine logging procedures and entries for both AT and TO. They will analyze logging data contained in databases. Researchers will construct a survey instrument and will visit a limited number of TO and AT field site locations. Researchers will interview AT and TO specialists, including individuals on working groups who are involved with logs. The data will be analyzed and redundancies will be identified.

Results: This is an ongoing effort. The results of this study will be used to identify ways to streamline processes.

Recent Accomplishments:

- Identified and obtained TO and AT procedures documents related to the communication of NAS system and equipment status
- Identified logs used to report and record NAS system and equipment status
- Developed a research plan
- Created Institutional Review Board material
- Submitted an application to Institutional Review Board for approval
- Obtained access to AFCC metrics database

Primary Investigator: Vicki Ahlstrom, FAA William J. Hughes Technical Center, Atlantic City International Airport, NJ

Password Alternatives

FAA Sponsor Organization: Technical Operations

Purpose and Rationale: As security concerns have increased, we have seen new requirements for password protection of software. This has lead to a proliferation of passwords. In a given office environment, it is not uncommon for a user to have six to 10 passwords to remember in order to access various systems. In order to maintain security, users are often forced to change passwords on a regular basis. Users then need to relearn the new password. Additionally, the passwords used by FAA systems are increasing in complexity. The combination of increased complexity, increased frequency of change and sheer numbers of passwords increase the probability that users will forget the passwords. Forgetting a password can add to the time it takes to solve a problem and can increase user workload.

Method: This study at the William J. Hughes Technical Center examined the advantages and disadvantages of different password and password alternative systems from a human factors perspective. The study was conducted in two phases. In phase one, researchers conducted a literature review and analysis of human factors considerations for passwords and other user identification techniques. Researchers related this analysis to the FAA Technical Operations (TO) domain and provided recommendations for improving the use of passwords in the field. They also describe areas for further investigation. In phase two, the researchers collected information on various password alternatives through structured interviews. They interviewed users to determine functional requirements for passwords and password alternatives. The researchers also conducted a field study to examine the human factors implications of user-identification techniques currently employed at field sites to prevent unauthorized access to NAS equipment and information technology systems. They documented findings from the field study and provided recommendations that are specific to TO users, tasks and environment. These recommendations seek to improve the human factors of user identification technologies and policies to improve the productivity, workload, and job satisfaction of TO employees.

Results: This project resulted in two technical notes and a conference presentation. Results of this study have been used to identify the extent and nature of the password issue for TO.

Recent Accomplishments: Two technical notes were written documenting this effort and the results were also presented at a conference.

Primary Investigator: Kenneth Allendoerfer, FAA William J. Hughes Technical Center, Atlantic City International Airport, New Jersey (609) 485-4864.

Human Factors of Personal Data Assistants (PDAs) and Hand Held Computer Devices

FAA Sponsor Organization: Technical Operations

Purpose and Rationale: The purpose of this project is to identify the human factors issues relevant to handheld and wearable computer devices. Technical Operation (TO) personnel are considering the use of hand held computers and Personal Data Assistants as a means of interacting with the NAS information management system. There is currently no set of human factors guidelines to evaluate these different systems. This could lead to a mismatch between user needs and the functionality provided by the device. Mismatches between user needs and the device can lead to increased errors, lowered performance, or ergonomic complaints by the users. By creating a set of guidelines, program managers can make informed decisions on what devices are suitable for the task, saving time and money.

Method: This set of criteria provides general recommendations for use. The researchers obtained current research on the use of these devices, extracted relevant information, and provided recommendations based on current research.

Results: Results of this study have been used to guide decision-making on handheld devices for use by TO personnel.

Recent Accomplishments: A technical note was written describing the results from this study.

Primary Investigator: Vicki Ahlstrom, FAA William J. Hughes Technical Center, Atlantic City International Airport, NJ.

Human Factors Engineering

Program manager Glen Hewitt directs activities focused on the application and integration of human factors engineering in systems acquisitions related to the definition, procurement, design, development, testing and implementation of diverse systems within the FAA and National Airspace System. Activities are conducted that are associated with building a human factors engineering program within the FAA and its systems engineering community. The program addresses: the application of human factors engineering during mission and requirements analysis and development; investment analysis; product analysis; design, development and testing; source selection preparation and evaluation; and post-deployment data collection and analysis.

The objectives associated with this program are designed to ensure that the incorporation of human factors engineering is explicit, timely, systematic, comprehensive, efficient and effective. Efforts relate to identifying and defining system-specific human factors requirements, assessing human factors risks, providing technical solutions to mitigate risks, advising on policy decisions related to human factors engineering, conducting human factors training, acquiring and supporting human factors tools and technologies, and implementing human factors plans. Technical support to system acquisition programs encompasses areas of study related to human-computer interface, staffing and training, workload, procedures, documentation, communications, and other salient human-system interface issues.

Human Factors in the National Airspace System (NAS) Enterprise Architecture (EA)

FAA Sponsor Organization: ATO-P

Purpose and Rationale: Ensure incorporation of human factors considerations in NAS Enterprise Architecture developments and modifications to enhance human-system integration in system engineering endeavors.

Methodology: Analyze NAS EA strategies and methods to identify and recommend changes that promote development of the Operational and Technical Views to a sufficient level of detail to identify and model human factors limitations and capabilities and their impact on NAS performance. Impacts include those related to human error, staffing levels, training requirements, and personnel selection.

Results: As a result of the initiation of human factors efforts related to the new development in the use of the Department of Defense Architecture Framework for the NAS EA, human factors processes and products have been identified as part of the NAS EA developmental strategy.

Recent Accomplishments: Recommendations have been made in the following areas:

- Human factors input to NAS Enterprise Architecture
- Synchronization of architecture, funding, and manpower plans
- Needs for NAS EA performance baseline
- Human factors requirements in Target System Descriptions and the NAS EA enhancements
- Support for current and projected views that represent other essential components such as facilities, training capability and plans, acquired and contracted services, and manpower availability
- Minimum requirements in multiple system engineering specialty disciplines
- Air-ground integration consideration and representative views
- Functional roles in developing the NAS EA Framework

Primary Investigators: Rebecca Gray (L-3 Communications, Titan Group Inc.), Glen Hewitt (ATO-P)

Human Factors Risk Identification and Mitigation in System Acquisitions

FAA Sponsor Organization: ATO Service Units

Purpose and Rationale: Assist in the identification and mitigation of human factors risks in system acquisitions so as to facilitate their resolution in a timely and efficient manner.

Methodology: Provide human factors services in support of other Air Traffic Organization elements as required.

Results: Support of ATO system acquisitions has resulted in the identification of human factors risks, the description of human factors risk mitigation strategies, and incorporation of plans to conduct tasks to resolve identified risks.

Recent Accomplishment: Direct product support has resulted in the creation, review, or update of human factors plans, human factors risk assessments and mitigation plans, system requirements documents, In-Service Review issue status and mitigation plans, and integrated safety plans.

Primary Investigator Glen Hewitt (ATO-P)

Human Factors in Safety Management

FAA Sponsor Organization: ATO-P/ATO-S

Purpose and Rationale: Incorporate human factors considerations in Safety Management System (SMS) policy, process, documentation, and training so as to ensure human factors has an opportunity to be adequately addressed in FAA safety related activities.

Methodology: Analyze Safety Management System (SMS) strategies and methods to identify and recommend changes that promote the human-system safety risk considerations that sufficiently identify human factors limitations and capabilities.

Results: As a result of initiating this new approach to human-system safety risks, human factors "best practices" have been identified in support of the enhancement of the Safety Management System.

Recent Accomplishment: Recent accomplishments include: conducting studies and analyses related to safety management; making recommendations about SMS policy and processes; suggesting approaches to safety oversight; providing tools for SMS practitioners; and, incorporating human factors considerations in SMS training.

Primary Investigators: Glen Hewitt, Dino Piccione (ATO-P); Rebecca Gray (L-3 Communications, Titan Group Inc.)

Human Factors Support to Airport Traffic Control Tower (ATCT) Siting

FAA Sponsor Organization: ATO-T (Facilities)

Purpose and Rationale: Incorporate human factors considerations into hazard assessment components of the Airport Traffic Control Tower Siting Order to promote the identification of human capabilities and limitations to tower siting decisions.

Methodology: Recommend inclusion of descriptions, criteria, and tools to support the identification of human capabilities and limitations for viewing objects on the airport surface.

Results: As a result of the development of criteria and tools, human performance considerations have been included in the draft revised Airport Traffic Control Tower Siting Order, 6480.XX

Recent Accomplishment: The draft revised Airport Traffic Control Tower Siting Order, 6480.XX, has been adopted as an interim solution to promote analysis of hazards and risks under the Safety Management System. The human factors visibility tool has been incorporated into the tower siting process affecting the siting and construction of all FAA tower projects.

Primary Investigators: William Krebs, Glen Hewitt (ATO-P)

Human Factors in Acquisition Management System Policy and Process

FAA Sponsor Organization: ATO-P/ATO-A

Purpose and Rationale: The overall goal of this work is to incorporate human factors considerations in Acquisition Management System (AMS) policy, process, and documentation to ensure that human factors has an opportunity to be adequately addressed in FAA system acquisitions.

Methodology: Throughout the year, members of this team monitored and reviewed AMS policy, processes, work groups, training, and other developments and activities, and recommended changes where appropriate.

Results: The team continued its efforts to enhance the potential for human factors considerations to be addressed in system acquisitions. This resulted in several changes to AMS processes and documentation. Incorporating human factors considerations in AMS training programs has increased awareness of the importance and scope of human factors, and has led to a better understanding of human factors best practices.

Recent Accomplishments:

- Revision and update of the FAA Acquisition System Toolset Human Factors Flowchart
- Inclusion of human factors considerations in the newly developed Post Implementation Review Guidance

- Usability and human factors input to the draft FAA Guide to OMB Exhibit 300
- Revision and update of the "Human Factors Assessments in Investment Analysis: Definition and Process Summary for Cost, Risk, and Benefits" to include standardized system engineering risk grid, OMB Exhibit 300 documentation, and AMS changes in terminology.
- Revision and update of the System Engineering Manual, section 4.8.3 Human Factors.
- Creation of draft Human Factors Guidance for Post-Implementation Reviews
- Human factors training in Fundamentals of the Acquisition Management System course
- Recommendations for changes in other AMS related training

Primary Investigators: Glen Hewitt, FAA (ATO-P), Rebecca Gray (L-3 Communications, Titan Group Inc.)

Aerospace Medical Research

Dr. Jim Whinnery manages an Aeromedical Research Program that addresses improved health, safety and survivability of aircraft passengers and aircrews. There are two major research areas: (1) toxicology and accident research, which evaluates medical findings gleaned from aircraft accidents to improve the safe operation of aircraft; and, (2) protection and survival research, which develops injury reducing materials and structures, and also evaluates survival equipment and procedures to protect aircraft occupants. The Aerospace Medical Research program is focused on the following:

- Identifying human failure modes (physiological, psychological, and clinical) in uneventful flight and during accidents and incidents. Here, researchers make formal recommendations for developing counteracting measures.

- Preparing bioaeronautical guidelines, standards and models for aircraft cabin equipment, procedures and environments as a basis for regulatory action to enhance appropriate human performance.

- Reviewing pilot medical and flight histories and information from accident and incident reports to develop new medical criteria, standards and assessment/certification procedures to ensure full performance capability.

- Preparing assessments of flight attendant and passenger behavior and disease issues and proposing guidelines for actions that improve the health and safety of cabin occupants.

Forensic Toxicology Research
Analysis of Thebaine, 6-MAM, and Six Opiates in Postmortem Fluids and Tissues

FAA Sponsor Organization: AAM-1, AAI-220

Purpose and Rationale: Opiates are some of the most widely prescribed drugs in America and are often abused. Demonstrating the presence or absence of opiate compounds in postmortem fluids and/or tissues derived from fatal civil aviation accidents can have serious legal consequences and may assist in determination of the cause of human impairment and/or death. However, the ordinary consumption of poppy seed products can result in a positive opiate drug test. Researchers at the Civil Aerospace Medical Institute (CAMI) have developed a simple method for the simultaneous determination of eight opiate compounds from a single analytical extraction procedure. These compounds are hydrocodone, dihydrocodeine, codeine, oxycodone, hydromorphone, 6-monoacetylmorphine, morphine, and thebaine. The inclusion of thebaine is notable as it is an indicator of poppy seed consumption and may help explain morphine/codeine positives in cases where no opiate use actually occurred.

Methodology: In this study, researchers incorporated a Zymark RapidTrace™ automated solid-phase extraction system, gas chromatography/mass spectrometry, and trimethyl silane (TMS) and oxime-TMS derivatives. This procedure resulted in the simultaneous extraction and determination of the eight opiate compounds.

Results: The methodology provided extraction efficiencies ranging from 70 – 100%. The limits of detection ranged from 0.78 – 12.5 ng/mL. The linear dynamic range for most analyzed samples was 6.25 – 1600 ng/mL. Researchers applied this method to postmortem tissues and fluids from eight separate aviation fatalities where opiate compounds had previously been detected. The method proved simple, robust and accurate for the determination of opiates in postmortem matrices, and in distinguishing opiate use from poppy seed consumption.

Recent Accomplishment: The consumption of products containing poppy seeds, such as bagels and muffins, can result in a person testing positive for morphine and codeine in a drug test. This person should also test positive for thebaine (a unique marker for poppy seeds). In contrast, a person taking prescription codeine will test positive for codeine and morphine, but not for thebaine. Until recently, toxicologists were unable to easily differentiate between codeine use and poppy seed consumption in a simple and timely manner. Forensic Toxicology Team scientists developed an accurate method to determine thebaine (poppy seeds), 6-MAM (unique heroine marker) and six opiates of abuse to aid in the investigation of aviation accidents. This methodology can, therefore, distinguish between the licit and illicit consumption of drugs in addition to the innocuous ingestion of poppy seeds in a diet.

Primary Investigators: Russell Lewis and Robert Johnson, CAMI

Biochemistry Research
Epidemiology of Toxicological Factors in Civil Aviation Accident Pilot Fatalities, 1999–2003

FAA Sponsor Organization: AAM-1, AAI-220

Purpose and Rationale: The prevalence of drug and ethanol use in aviation is monitored by the FAA. Under such monitoring, epidemiological studies for the 1989–1993 and 1994–1998 periods indicated lower percentages of the presence of abused drugs than that of prescription and nonprescription drugs in aviation accident pilot fatalities. As part of the continuous evaluation of drug and ethanol use in aerospace operators, an epidemiological assessment was made for an additional period of five years (1999-2003).

Methodology: Postmortem samples from aviation accident pilot fatalities submitted to the Civil Aerospace Medical Institute (CAMI) are toxicologically analyzed, with the analytical findings stored in the Forensic Toxicology database. This database was examined for the period of 1999–2003 for the presence of controlled substances in Schedules I–V, prescription and nonprescription drugs, and ethanol in the pilot fatalities.

Results: Out of 1,629 fatal aviation accidents from which CAMI received biosamples, there were 1587 accidents wherein pilots were fatally injured. Drugs and/or ethanol were found in 830 of the 1587 (52%) fatalities. Controlled substances of Schedules I and II and Schedules III–V were detected in 113 and 42 pilots, respectively. Prescription drugs were present in 315 pilots, nonprescription drugs in 259 pilots, and ethanol in 101 pilots. Controlled substances of Schedules I and II were detected in only five of the 122 First-Class medical certificate-holding airline transport pilots. In addition to the controlled substances, many of the prescription and nonprescription drugs found in the fatalities have the potential for impairing performance, thereby adversely affecting the ability of an individual to optimally pilot an aerospace craft.

Recent Accomplishment: Findings from this epidemiology study were consistent with those of the two previous epidemiological studies and add support for the FAA's program requirement, including the FAA's drug-testing program, aimed at identifying potentially incapacitating medical conditions and reducing the usage of performance-impairing drugs or ethanol. These findings are used by regulators to take necessary steps to continue and further enhance aviation safety.

Expert opinions of team members were sought by National Transportation Safety Board accident investigators for postmortem aviation toxicology result interpretations and by FAA attorneys for workplace forensic urine drug testing litigation cases. Members of the team were heavily involved in maintaining the quality control/quality assurance program and accreditation of the laboratory, in developing an organization level Quality Management System, in developing a standard associated with fire threat to people and the environment, and in effectively reinforcing organizational safety standards.

Primary Investigators: Arvind K. Chaturvedi and John Soper

Functional Genomics Research:
Gene Expression Changes in Response to Mild Alcohol Ingestion

FAA Sponsor Organization: AAM-1

Purpose and Rationale: This study at the Civil Aerospace Medical Institute was designed to investigate gene expression changes in response to mild alcohol ingestion. The research served as a proof of concept for questions that need to be answered concerning whether or not microarray analysis would be sensitive enough to detect gene expression changes in a person who is not a chronic alcohol abuser. Other hypotheses that were tested in the course of this study included: (1) different gene expression profiles could be detected at different blood alcohol levels; and, (2) a non-baseline gene expression profile could be detected subsequent to blood alcohol levels returning to zero. A key long-term goal of this research is to discover a molecular signature that differentiates between various blood alcohol levels. This will benefit forensic science effort by allowing for the separation of samples that are positive for alcohol due to normal microbial activity from those that are positive due to pre-mortem ingestion.

Methodology: Peripheral whole blood samples were acquired from six subjects at five time points. The time points corresponded to blood alcohol levels of 0.00%, 0.04, 0.08, 0.04 and 0.00. RNA was purified from the subject blood samples. Biotin labeled target material was made from the purified RNA by *in vitro* transcription amplification. Target material was hybridized to Affymetrix HgU133plus2.0 oligonucleotide microarrays and scanned using an Affymetrix scanner. Differential expression analysis was performed using the Local Pooled Error t-test after data summarization and normalization on all pair-wise comparisons across blood alcohol levels.

Results: The raw data was summarized to transcript level signal intensities by robust multi-array averaging (RMA). RMA summarizes the data based on the total fluorescence intensity of the probes representing the exact sequence of each transcript. GC-RMA summarizes the probe level data after subtracting probes representing less-than-perfect (mismatch probes, MM) sequence hybridization as representative of background fluorescence. All data was normalized by the quantile method to remove non-biological variability across the arrays. The RMA summarized/quantile normalized data set returned 460 probe sets that were differentially expressed to statistical significance, ($p<0.05$ with Benjamini-Hochberg correction for multiple analyses) in at least one pair wise comparison. The GCRMA summarized/quantile normalized data set returned 263 statistically significant probe sets that were differentially expressed within at least one comparison. The intersection of these two resulting data sets, after filtering for >1.5 fold change, returned 111 probe sets. A wide range of biological processes are represented in these 111 probe sets including DNA, RNA and protein metabolism, transcription, glycoside hydrolase acitivity, several types of kinase activity, modulation of the immune response, cytoskeletal integrity and drug clearance. Definition of the specific biological processes that can be utilized for determination of alcohol's contribution to an aerospace accident or incident should be contained within these probe sets.

Recent Accomplishment: This study has demonstrated the efficacy of microarray analysis for mild alcohol consumption when whole blood is the starting material. Furthermore, the study demonstrated that microarray gene expression analysis has the required sensitivity to detect gene expression changes in response to mild alcohol use, that gene expression profiles differ in response to blood alcohol levels, and that gene expression profiles after blood alcohol levels have

returned to zero differ dramatically from a blood alcohol level of zero before alcohol ingestion. Furthermore, pathways for further investigation have been discovered that have potential for validation and further investigation by more sensitive techniques. Using all the tools available, a combination of the results from this microarray experiment and more sensitive methods will lead to a robust assay for alcohol ingestion that can be utilized to enhance aerospace safety.

Primary Investigators: Dennis Burian, Vicky White, Dennis Canfield, Doris Kupfer (DNA Solutions), Mark Huggins (Advancia), Dave Strayer (University of Utah), and Dennis Crouch (University of Utah).

Radiobiology Research
Modify CARI-6 Interactive Computer Programs to Improve Estimation of Solar Activity Effects on Galactic Cosmic Radiation during Aerospace Flight

FAA Sponsor Organization: AAM-1

Purpose and Rationale: Inadequacies were recently discovered in the methodology associated with the estimation of the solar wind effects on galactic cosmic radiation. Corrections required revision of the CARI programs which provide dose estimations to air carrier crewmembers. The corrections will also permit epidemiologists worldwide to enhance their estimations of the health effects of galactic cosmic radiation exposure of humans in aerospace environments.

Methodology: Researchers at the Civil Aerospace Medical Institute improved interpretation of ground level neutron monitor data by incorporating newer nuclear physics research revealed the inadequacies in solar wind effects on galactic cosmic radiation. Neutron monitor data is used to calculate the galactic cosmic ray spectrum incident on the earth's atmosphere. Results from the revised galactic cosmic ray spectrum calculations are incorporated into the CARI programs by means of a parameter called the heliocentric potential.

Results: An improved method of calculating heliocentric potential was developed. The CARI program is widely used in the world for the calculation of flight doses of galactic cosmic radiation. Aviation groups, government organizations, scientists, physicians, and individuals worldwide depend on it to ensure their safety.

Recent Accomplishment: The improved method of calculating heliocentric potential has been used to revise past heliocentric potentials for users of the CARI programs. This improved method facilitates calculation of past radiation exposures for epidemiological, medical, and regulatory purposes that are aimed at ensuring human safety.

Primary Investigators: Wallace Friedberg, Kyle Copeland

Bioinformatics Research
Develop a Scientific Information System to Enable Comprehensive Examination and Study of the Epidemiology of Pilot-Related Mishaps (Accidents and Incidents) Related to Bioaeronautical Causes, using Aeromedically Optimized Record Sets of Aviation Safety and Medical Certification Data.

FAA Sponsor Organization: AAM-1

Purpose and Rationale: The goal of this research at the Civil Aerospace Medical Institute is to develop state-of-the-art methods to analyze very large, complex aeromedical datasets.

Methodology: Researchers focused on three key concepts: (1) Maintain and enhance bioinformatics expertise and capability including the study of government information factories, laboratory information systems, and scientific information systems; (2) Develop methods, systems, and processes to create, manage and distribute digital research content; and, (3) Remain current in visualization of aeromedical research data in multiple media domains.

Results: Researchers were successful in achieving the following:

- Identifying and correcting a large data anomaly problem in historical records covering a five-year period. By solving this data quality problem, approximately one million additional medical certification examination records could be utilized in aviation safety analyses.
- Collaboration in and bioinformatic support of research projects with the Functional Genomics Research and Environmental Physiology Research Teams. Members of the team conducted blood leucocyte gene expression microarray analysis and data storage from subjects consuming alcohol in a driving simulation.
- Computational research-unique hardware was developed and software support of instrumentation and databases was provided to the Aerospace Medical Research Division.
- Important data issues regarding the coding of spatial disorientation accidents leading to an incorrect depiction of a decrease in spatial disorientation mishaps were identified. Following this, more accurate estimates were calculated based upon empirical review of National Transportation Safety Board mishaps using an inter-rater blinded comparison of mishap reviews.

Recent Accomplishments: Researchers developed techniques to model very rare events, such as human performance related aviation accidents due to medical or other human factors. As a result, the team completed the evaluation of atrial fibrillation and flight safety in civilian aviation. This analysis served as the prototype methodology for future analysis across a broad spectrum of aeromedical research studies.

Primary Investigators: Stephen J.H. Véronneau, Connie L Peterman, Paul Rogers, Marc Davidson.

Cabin Safety Research
Improving Survival in Airplane Emergencies

FAA Sponsor Organization: AAM-1, ANM-115

Purpose and Rationale: The Civil Aerospace Medical Institute's Cabin Safety Research (CSR) Team evaluates the design and operation of transport airplanes to identify cabin safety problems that need to be addressed and conducts research studies to eliminate these problems and improve survival in airplane emergencies. The research team also evaluates the efficacy of equipment and procedures used in airplane emergencies. Such research efforts are aimed toward improvements based primarily on the human factors of emergency situations.

Methodology: Researchers evaluate various aspects of cabin safety (e.g., emergency evacuation) through literature reviews, computerized mathematical modeling, and laboratory/field research studies employing human subjects. Unique apparatus dedicated to laboratory research includes a large water survival tank, both narrow- and wide-body aircraft simulators, aircraft emergency escape systems and equipment, and adjunctive laboratory facilities required to support processing and care of large numbers of research subjects. Expert on-site field support is also provided to industry research and testing efforts related to certification of transport airplanes and emergency equipment, as well as implementation of effective emergency procedures.

Results: A major FY 2005 effort was directed toward providing scientific expertise and support for FAA certification of two transport airplanes, the Embraer ERJ-190 and the Airbus A-380. Activities included preparation for and evaluation of the successful ERJ-190 full-scale evacuation demonstration, as well as identification, evaluation, and disposition of myriad cabin safety issues related to certification of the Airbus A-380 double deck, Very Large Transport Aircraft (VLTA). The size, complexity and international focus of the Airbus A-380 certification effort required extensive international travel and coordination. As part of the certification effort, CSR Team members have monitored industry testing of evacuation slides, participated in the development of detailed test plans, and coordinated test-monitoring activities. Activity continues with primary emphasis being placed on the emergency evacuation capability of the airplane. The full-scale evacuation demonstration is currently forecast to be conducted in the spring of 2006.

The CSR Team, through membership and active participation on the Cabin Safety Research Technical Group (CSRTG), supported the planning, preparation, and implementation of the 4th Triennial International Aircraft Fire and Cabin Safety Research Conference, held in Lisbon, Portugal. CSR Team members presented six scientific papers, and collaboration was achieved with aircraft fire and cabin safety research scientists and engineers from across the world.

Recent Accomplishment: Computerized aircraft evacuation modeling efforts are underway through a research grant to Rutgers University. The focus of the modeling is to develop a Windows-based desktop environment in which FAA users can evaluate a wide range of changes to the airplane, its emergency escape systems, emergency procedures, and other safety related components on emergency evacuation efficiency. FY 2005 developments included a collaborative funding activity with the Office of Aviation Research, Airport Safety Technology Section (AAR-411) to define the relative improvement in evacuation capability that could be achieved by reinstatement of lost evacuation capability through use of a mobile evacuation-system-equipped fire-fighter vehicle. This vehicle has a platform and equipment that could be used to tear

additional openings in a crashed aircraft and facilitate evacuation. The evacuation model demonstrated that such a rescue vehicle could be of value and supported decisions for its continued development.

Primary Investigators: Garnet A. 'Mac' McLean, Cynthia L. Corbett, David A. Palmerton , Kenneth G. Larcher.

Biodynamics Research
Evaluation of Aircraft Occupant Restraint Systems and Seats

FAA Sponsor Organization: ANM-113

Purpose and Rationale: The Biodynamics Research Team evaluates the injury potential of new materials and structures by utilizing advanced computational and impact test techniques under simulated crash environments. The team also supports other FAA elements in conducting dynamic tests. New methods, techniques, and equipment are developed for evaluating aviation injury potential. In addition, the team provides research products to directly support FAA aircraft certification and rule making organizations in the areas of aviation crash protection and restraint system technology.

Methodology: Researchers utilize the Civil Aerospace Medical Institute (CAMI) impact test sled, static test procedures, mathematical dynamic models, instrumented anthropometric test dummies, high speed digital video recording and other research tools to evaluate aircraft occupant restraint systems and seats. Results are often of a sensitive nature and are provided directly to FAA sponsors.

Results: During the past year, the Biodynamics Research Team conducted over 60 sled tests to evaluate a range of aircraft seat cushion materials and thicknesses. The seats and cushions in current aircraft were initially certified as a single unit using either static or dynamic test procedures. Validated test procedures, however, were not available to certify individual components or replacement parts of the seats. The objective of these tests was to develop procedures that seat manufacturers could use to facilitate certification of replacement seat cushions. The tests series provided data to support determinations that alternative test procedures and criteria could be applied to replacement seat cushions. The results were included in FAA Office of Aviation Research Report DOT/FAA/AR-05/5 Development and Validation of an Aircraft Seat Cushion Component Test – Volume I, dated March 2005. The test methods developed in this effort formed the basis of a new Policy Statement, ANM-115-05-005 issued 08/09/2005. This policy change is part of an FAA effort to streamline the seat certification process for manufacturers and reduce the costs and time associated with seat certification.

The FAA Biodynamic Test Team used data gathered from both CAMI and industry seat belt testing to assist the FAA Transport Directorate in developing a new policy for seatbelt replacement. Policy Statement ANM-115-05-10 implemented the modified test procedures. This policy will streamline the seat certification process and will assist the FAA in meeting requirements to reduce the costs and time associated with seat certification.

Recent Accomplishment: The Biodynamics Research Team conducted a series of sled tests to evaluate energy- absorbing features of seats designed for a new general aviation aircraft. Most energy absorbing features of aircraft seats involve the use of mechanical shock absorbers, shoulder strap break devices and other technologies that tend to add weight, complexity and cost to the aircraft. In the experimental seat test, the seat pan and shoulder strap attachment both used bending metal type energy absorbers to reduce spinal and shoulder strap loads. Bending metal shock absorbers rely of the energy absorbing capability of the metal to reduce acceleration loads rather than more complex mechanical devices. Such cost effective technologies could be easily adapted to other seat designs to improve safety based on these research results.

Primary Investigators: Rick DeWeese, David Moorcroft.

Environmental Physiology Research
Aircraft Environment and Aircrew Protection Systems

FAA Sponsor Organization: ANM-110, AAM-1, AAR-440

Purpose and Rationale: The Environmental Physiology Research (EPR) Team studies environmental factors and biological/chemical threat environments that detrimentally influence human functioning, physiology, and safety in aerospace environments. The team evaluates emergency situations to determine the adequacy of protective systems for altitude and potentially threatening or toxic aircraft environments. The team also developments improved test methodologies/procedures to optimize performance in the face of aviation related environmental hazards.

Methodology: The EPR Team conducts literature reviews and coordinates with key standards groups to maintain awareness of state-of-the-art aircrew protective systems. The team uses a full range of physiological test devices, the altitude chamber, a flight deck environment simulator, and the 747 Aircraft Environment Research Facility to conduct experiments and evaluations of aircraft environment and aircrew protection systems.

Results: In 2005, the EPR Team initiated a performance evaluation of oxygen systems designated for use in general aviation aircraft at altitudes of up to 25,000 feet. These new systems capitalize on the human breathing cycle to conserve aircraft oxygen supplies by providing an oxygen pulse during inhalation and no oxygen flow during exhalation. Current FAA regulations define requirements for continuous flow oxygen systems (systems that provide a constant flow of oxygen throughout the breathing cycle) and demand oxygen systems (military type oxygen systems that use tightly sealing full face masks). Requirements for pulse oxygen systems that have characteristics of both continuous flow and demand oxygen systems are not defined in FAA regulations. The test protocol will evaluate pulse oxygen systems from two different manufacturers. The systems will use nasal cannula to 18,000 feet of altitude and nasal-oral masks from 18,000 to 25,000 feet. The results of this study will support certification decisions relative to pulse oxygen systems and will establish a physiological basis for new regulations.

The EPR Team provided consultation for the halocarbon handheld fire extinguisher advisory circular (AC) development team. This AC will contain instructions for use of the halocarbon fire

extinguishers that replace the halon fire extinguishers currently in use. The AC development team was concerned that discharge of a fire extinguisher in a small volume aircraft cabin at altitude could result in a hypoxic situation. The EPR Team conducted a literature review and consulted on the combined effects of the fire suppression agent and altitude.

As a member of the FAA Aircraft Cabin Environment Research Team (ACERT), the EPR Team coordinated development of a research grant with Smiths Detection, Inc. to develop a chemical sensor system for aircraft cabins. Smiths proposes to use a system of microarray detectors to sense chemical contaminants in the aircraft cabin. If successful, this technology may provide capability for detection and warning of intentionally and/or unintentionally released contaminants. This research will be conducted in conjunction with other sensor technology efforts undertaken by the Airliner Cabin Environmental Research (ACER) Center of Excellence (COE). In direct support of the ACER COE, the EPR Team initiated a program with Oklahoma State University (OSU) to conduct research on the physiological and medical effects of exposure to reduced atmospheric pressure in the altitude ranges currently found in a normal airliner cabin environment. In coordination with the Boeing Company, OSU recently completed an altitude study that provided information to define an optimum cabin altitude for humans. The FAA/OSU efforts will support further definition of potential health effects that may be related to altitude exposure in healthy and unhealthy (with disease) people who fly in civilian aircraft.

Recent Accomplishment: In 1996, the FAA established a policy allowing Class III (Private Pilot) medical certification of insulin dependent diabetics, provided they demonstrate satisfactory control of their disease continuously. For some insulin dependent pilots, control of the disease depends on the use of an insulin pump. The design of some pumps indicate that they may not adequately compensate for altitude pressure change; thus, a project was initiated to conduct testing to determine the adequacy of normal operation of these pumps at altitudes from 8,000 feet to 25,000 feet. This information will assist medical personnel in determining the adequate function of these pumps in association with medical certification decisions in pilots with insulin-dependent diabetes.
Primary Investigators: Dr. Arnold Angelici and Mr. Robert Shaffstall

Medical Research
Issues that Contribute to an Accident or to Injuries Associated with an Accident

FAA Sponsor Organization: AAM-1, AAI-220

Purpose and Rationale: The Civil Aerospace Medical Institute's Medical Research Team (MRT) conducts medical and laboratory studies of aircraft accident victims, including invited on-site participation in selected cases. The team analyses medical, engineering and human factors findings from aircraft accidents and conducts appropriate research into the relationships of findings to the safe operation of aircraft. The team develops methods for better understanding of the causal factors in aircraft accidents and evaluates performance decrements resulting from disease/physiological processes to determine their effects on aerospace safety. The team also conducts research to develop aeromedical/life support equipment guidelines for commercial space operations.

Methodology: The MRT conducts studies to evaluate current and anticipated medical and human factors issues that contribute to an accident or to injuries associated with an accident. The team supports aircraft accident investigations and answers queries related to aerospace medicine. Research efforts support the airman medical certification process and provide information relative to pathology that may affect human performance and safety of flight operations. An important aspect of this research is the maintenance of comprehensive databases pertaining to cockpit and cabin safety-related factors in general aviation and transport aircraft. This team serves the agency as an advisory resource in areas relating to aerospace medical and human factors issues that affect aerospace safety.

Results: Based on current and previously conducted research, the MRT provided consultation to US government agencies, industry, academia and the flying public. Significant consultations included database research analyses to provide information on in-flight incapacitation accidents or incidents in which the airman had undisclosed related medical conditions. This study evaluated airline pilot incapacitation/impairment over a five-year period from 1993 – 1998. During this period, 48 incapacitation or impairment events were documented resulting in an incapacitation/impairment rate of 0.099/100,000 flights or approximately one event per every 1,000,000 flights. The most frequently listed cause of the impairment or incapacitation was loss of consciousness, followed by cardiac related symptoms and other neurological symptoms.

In 1999, the MRT conducted a study utilizing information from MedAire, a consultation and service company that provides medical services for airlines, to determine the frequency of use for Automatic Electronic Defibrillators (AEDs). The 1999 study provided information that supported the installation of AEDs in all commercial airliners. As a follow-up to the 1999 effort, the MRT coordinated with MedAire to obtain information on in-flight illness/injury and the use of medical equipment including the AEDs. Analysis of this report is ongoing in an effort to identify an index of passenger health and compare the index to prior years in support of future planning concerning AEDs and Emergency Medical Kits.

The MRT continuously provided aeromedical-consulting support during aircraft accident investigations to the FAA Office of Accident Investigation. In addition, a research project to develop guidelines for commercial space vehicles was completed. This effort was supported by the FAA Office of Commercial Space Transportation (AST) and conducted through the National Research Council's (NRC) Postdoctoral Research Associate's program. The NRC postdoctoral research associate collaborated with government and industry scientists and engineers to develop a document designed to assist regulators and space developers in establishing safe parameters for the human occupation of commercial space vehicles.

Recent Accomplishment: The MRT established a grant program with Wright State University to conduct research and develop an Aviation Autopsy/Injury Research Program. The objective of this program is to improve the utilization of injury data, incorporate the capability to classify severity of injury, and identify the injury mechanisms in aviation accidents. Initial work in this program provided a description of injuries in civilian female pilots.

Primary Investigators: Charles DeJohn, Eduard Ricaurte (Wright State University).

Vision Research:
Outdoor LASER Operations

FAA Sponsor Organization: AAM-1, AFS-300, AAM-400, AIR-130

Purpose and Rationale: The Civil Aerospace Medical Institute's Vision Research Team (VRT) performs studies that promote aviation safety by investigating topics related to vision and their effect on aviation personnel and operations. VRT activities include: supporting the medical certification process by assessing the benefits and liabilities of ophthalmic devices and surgical corrective procedures; evaluating the effects of aging and chronic disease on visual performance; identifying suitable vision screening procedures and techniques for the assessment of visual performance; and reviewing vision standards and their effectiveness for aerospace personnel.

Methodology: Research activities are performed by VRT members with expertise and experience involving a broad range of vision-related technologies, physiology, and science. Researchers investigate various aspects of vision and aviation safety by reviewing scientific literature and conducting analysis of medical and accident/incident databases including off-site data acquisition and analysis efforts. When appropriate, human subject testing is conducted in the VRT's vision laboratory that includes state-of-the-art ophthalmic instruments and a fully equipped refracting lane.

Results: In 2005, **t**he VRT provided technical support and ophthalmologic expertise to assist in development of a Department of Transportation (DOT) Advisory Circular, "Outdoor LASER Operations" (AC No: 70-1). The document provides information to LASER users on how to notify the FAA concerning proposed outdoor laser operations. The Advisory Circular includes a new FAA form for notification of conducting outdoor laser operations and detailed instructions on how to complete the FAA Form -- Notice of Proposed Outdoor LASER Operation(s).

From January 2004 to January 2005, there were 90 reports of civilian aircraft LASER illuminations, with 53 of these reports proceeding from commercial aircraft. Thirteen of the 90 reports resulted in some degree of pilot visual impairment or distraction. In response to these reports involving potentially hazardous illumination of airliners by LASERs, the VRT supported the development of another DOT Advisory Circular, "Reporting of LASER Illumination of Aircraft." This Advisory Circular was published by FAA ATO-R (System Operations Security). The document provides information on reporting of LASER illumination of aircraft, and aircrew mitigation procedures if illuminated by a LASER light. The Secretary of Transportation held a press conference at the FAA's Civil Aerospace Medical Institute in Oklahoma City on January 12, 2005, to announce the publication of this document.

Also in response to the increase in LASER incident reports, the VRT collaborated with the US Army to conduct LASER transmission testing of eight representative aircraft windscreens. These tests addressed safety concerns of both the Department of Homeland Security (DHS) and the FAA. The DHS is developing a system that may use a LASER to defeat or disable hand-held anti-aircraft missiles used by terrorists as a weapon against civilian aircraft. While the DHS was concerned that the use of such a system could unintentionally affect other aircraft, the FAA was interested in information on the spectrum and intensity of LASER energy that could pass through aircraft windows. Partial analysis indicated that, as expected, LASERS in the visible light spectrum easily transmitted through cockpit glass; however, toward the red end of the color spectrum, the transmission is decreased.

Recent Accomplishment: The VRT Team Coordinator participated in the U.S. House of Representatives Aviation Subcommittee staff briefing concerning LASERS.

Primary Investigators: Van Nakagawara , Ronald Montgomery